BOLTON

TM 11-6615-202-35

DEPARTMENT OF THE ARMY TECHNICAL MANUAL

FIELD AND DEPOT MAINTENANCE MANUAL

AUTOMATIC PILOT
AN/ASN-23

HEADQUARTERS, DEPARTMENT OF THE ARMY
JANUARY 1960

WARNING

DANGEROUS VOLTAGES EXIST IN THIS EQUIPMENT

Be careful when working on the control gyro
and amplifier 300-volt power supply circuit,
or on the 115-volt, AC line connections.

DON'T TAKE CHANCES!

TECHNICAL MANUAL

Field and Depot Maintenance Manual

AUTOMATIC PILOTS AN/ASN–23 AND AN/ASN–23 (MODIFIED)

TM 11–6615–202–35
CHANGES No. 1

HEADQUARTERS,
DEPARTMENT OF THE ARMY
WASHINGTON 25, D.C., *2 March 1962*

TM 11–6615–202–35, 18 January 1960, is changed as indicated so that the manual also applies to Automatic Pilot AN/ASN–23 (Modified). This publication represents information available at this time.

Change the title of the manual to read as above.

Change "Helicopter H–34A" to "Army Model H–34C Helicopters" in the following places:

Page 58, paragraph 28*a*, line 1.

Page 59, paragraph 29*a*, line 2.

Page 2, paragraph 1. Make the following changes.

Subparagraph *a*. Delete the first sentence and substitute: This manual covers field and depot maintenance for Automatic Pilot AN/ASN–23 and Automatic Pilot AN/ASN–23 (Modified) as installed in Army Model H–34C and H–37B Helicopters, respectively.

Subparagraph *b*. Delete and substitute:

b. The complete technical manual for this equipment includes TM 11–6615–202–12 and TM 11–6615–202–35P.

Subparagraph *c*. Delete and substitute:

c. Forward all comments on this manual direct to the Commanding Officer, U.S. Army Signal Materiel Support Agency, ATTN: SIGMS–PA2d, Fort Monmouth, N.J.

1.1. Differences in Equipment
(Added)

Automatic Pilot AN/ASN–23 differs from Automatic Pilot AN/ASN–23 (Modified) in the following details:

a. Motor Box Assembly S1645–61145 (AN/ASN–23) differs slightly from Motor Box Assembly S1591–90005 (AN/ASN–23 (Modified)) in internal circuitry. Refer to figures 77 and 77.1 for circuit differences.

b. Servo Motor Assembly S1665–61755 (AN/ASN–23) is identical with Servo Motor Assembly S1665–61755–5 (AN/ASN–23 (Modified)) except for the turns-ratio of the motor and tachometer generator. These models are not interchangeable.

c. The tail rotor servo unit assembly is used in Army Model H–34C Helicopters only.

d. Vertical Gyro Indicator 4005H is used with, but is not part of the AN/ASN–23 (Modified).

Section I.1. AUTOMATIC PILOT AN/ASN–23 (MODIFIED) OVERALL BLOCK DIAGRAM THEORY
(Added)

2.1. General

a. Automatic Pilot AN/ASN–23 (Modified) stabilizes the helicopter in a desired flight attitude. Any attempt of the helicopter to change from the established flight attitude is corrected by the autopilot unless the attitude change is introduced by the pilot through the normal use of the helicopter flight controls.

b. The autopilot incorporates four control channels: pitch, roll, yaw, and altitude. In each channel, an appropriate electrical displacement signal is initiated, modified, and amplified to produce a control voltage for the servomotor assembly. The servomotor assembly actuates the helicopter flight control system to offset the helicopter displacement signal.

2.2. Autopilot System, Block Diagram Analysis (fig. 5.1)

a. The 115-volt ac, phase A and C, and the 28-volt dc inputs from the helicopter electrical system are routed through the ac and dc interlock relays. These relays control the application of both ac and dc power to the autopilot system. Failure of either input power source will deenergize the associated relay and remove power from the system. Phase A of the ac input is applied from the dc interlock relay to the time-delay relay. After system warmup, closing the control panel ENG switch energizes the emergency release relay and the time-delay relay. After approximately 2½ minutes, the time-delay relay energizes, applying phase A voltage to the motor box and excitation voltage to the servomotors. Energizing 28 volts dc for the emergency release relay is routed from the ac interlock relay through the control gyro and amplifier to the pilot's and copilot's normally closed stick release switches, on the grip of their cyclic control sticks. Opening of either switch removes ac power from the motor box and servomotors and deenergizes all mode control relays in the gyro control and amplifier. Pressing the ENG switch also supplies 28 volts dc for all the mode controls relays in the control gyro and amplifier and supplies dc operating voltage for the altitude control and vertical gyro indicator. Normally closed switches are located in the pilot's and copilot's right and left tail rotor control pedals. These switches are connected in series and receive 28 volts dc from the ac interlock relay through the control gyro and amplifier and control unit. Breaking the contacts of any of these switches opens the yaw control channel. When the yaw control voltage is removed from the engage relay, it disengages any yaw displacement signal. This action prevents opposition from the autopilot to the manual turn being executed by the pilot. Removing foot pressure from the tail rotor control pedal switch at the completion of a turn closes the pedal switch and reengages the yaw channel engage relay. During autopilot warmup, 115 volts ac, phase A and C, is supplied from the dc interlock relay to the ac power distribution circuits in the control gyro and amplifier and to the vertical gyro indicator. Excitation voltage for the altitude control is supplied from the power distribution circuit in the control gyro and amplifier.

b. Displacement signals are developed in one or more of the four axes (pitch, roll, yaw, and altitude) whenever the helicopter deviates from an established flight attitude. These signals indicate the amount and direction of deviation. Changes in the helicopter pitch and roll axes are detected by the vertical gyro assembly. Altitude displacement signals are developed by the altitude control, which senses barometric pressure changes received from the purifier chamber. The purifier chamber is vented to the outside of the helicopter. Yaw displacement signals are obtained from the directional gyro in the J–2 compass system. The pitch, roll, and altitude displacement signals are applied through the control gyro and amplifier and the motor box to separate servomotors. The servomotors correct the helicopter displacement by mechanically driving the hydraulic servo units (in the servo unit) to control the main rotor flight control system. Rotation of the servomotor assembly produces a feedback voltage that is fed to the control gyro and amplifier.

c. The yaw displacement signal is applied through the control panel, the control gyro and amplifier, and the motor box to the yaw servomotor. The yaw servomotor corrects the helicopter displacement heading by mechanically driving the yaw hydraulic servo unit (in the servo unit) to control the tail rotor flight control system. The yaw displacement signal is supplied through the control panel to enable the pilot to make slight heading changes by using the YAW TRIM control on the control panel without the use of the tail rotor pedals. The pitch and roll signals from the vertical gyro are also applied to the vertical gyro indicator so that the indicator can display the position of the helicopter with respect to the horizon.

Note. Operation of the yaw servomoter is identical with the operation of the pitch, roll, and altitude servomotors.

d. The pilot or copilot may override the autopilot at any time to change the helicopter to a new flight attitude through the normal use of the helicopter flight controls. The cyclic control stick grip is mechanically coupled to the helicopter flight control system and mechani-

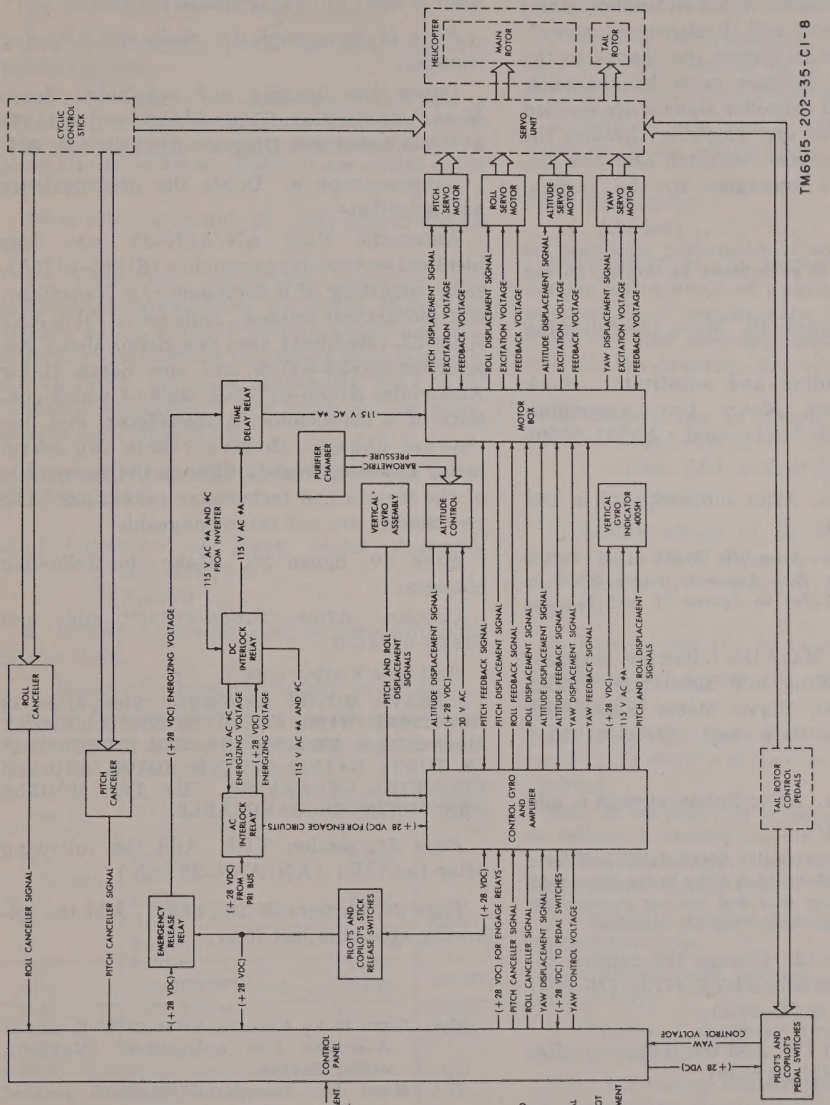


Figure 5.1. (Added) *Automatic Pilot AN/ASN-23 (Modified), block diagram.*

cally linked to the pitch and roll cancellers. Movement of the cyclic control stick grip results in pitch and roll canceller signals from the pitch and roll cancellers. The vertical gyro is unable to differentiate which attitude deviations are desirable and which are undesirable; therefore, pitch and roll displacement signals are also generated to oppose the change in the established flight attitude made by the pilot. The pitch and roll canceller signals are applied to the control gyro and amplifier through the control panel to cancel the pitch and roll displacement signals generated by the vertical gyro.

Note. For complete troubleshooting procedures for the autopilot, refer to paragraphs 34 through 36 and TM 11–1520–203–35.

Page 18, paragraph 10. Make the following changes:

Delete the heading and substitute: Block Diagram Analysis, Motor Box Assemblies S1645–61145 (H–34C) and S1591–90005 (H–37B).

Subparagraph *a.* After subparagraph *a,* add the following note:

Note. Motor Box Assembly S1645–61145 differs slightly from Motor Box Assembly S1591–90005 in internal circuitry. Refer to figures 77 and 77.1 for circuit differences.

Paragraph 11. Make the following changes:

Delete the heading and substitute: Block Diagram Analysis, Servo Motor Assemblies S1665–61755 (H–34C) and S1665–61755–5 (H–37B).

Subparagraph *a.* After Subparagraph *a,* add the following note:

Note. Servo Motor Assembly S1665–61755 and Servo Motor Assembly S1665–61755–5 differ in the turns ratio of the motor generator only and are not interchangeable. However, schematically they are identical.

Page 19, figure 12. Change the caption to: *Servo Motor Assemblies S1665–61755 (H–34C) and S1665–61755–5 (H–37B).*

Page 21, section IV. Add the following after the title: (AN/ASN–23 only).

Page 45, paragraph 20. Make the following changes:

Delete the heading and substitute: Motor Box Assemblies S1645–61145–1 and S1591–90005, Schematic Diagram Analysis (figs. 77 and 77.1).

Add the following note below the heading.

Note. Motor Box Assembly S1591–90005 used in Army Model H–37B Helicopters has been modified. Refer to figure 77.1 for differences in circuitry.

Page 49, paragraph 21. Make the following changes:

Delete the heading and subsitute: Servo Motor Assemblies S1665–61755 and S1665–61755–5, Schematic Diagram Analysis (fig. 20).

Subparagraph *a.* Delete the first sentence and substitute:

Automatic Pilot AN/ASN–23 uses four identical servomotor assemblies (S1665–61755), each consisting of a servomotor, a transducer, and mechanical linkage. Automatic Pilot AN/ASN–23 (Modified) uses two Servo Motor Assemblies S1665–61755 and two Servo Motor Assemblies S1665–61755–5, each of which consists of a servomotor, a transducer, and mechanical linkage. However, these two servomotor assembly models differ in the turns ratio of the motors and tachometer generators. The two models *are not* interchangeable.

Page 50, figure 20. Make the following changes:

Caption. After *"S1665–61755"*, add: *and S1665–61755–5*

Add note 8 after note 7.

8. SERVO MOTOR ASSEMBLY S1665–61755 IS IDENTICAL WITH SERVO MOTOR ASSEMBLY S1665–61755–5, EXCEPT FOR THE DIFFERENCE IN TURNS RATIOS OF THE MOTOR AND TACHOMETER GENERATOR. THE TWO MODELS *ARE NOT* INTERCHANGEABLE.

Page 58, section VIII. Add the following after the title: (AN/ASN–23 only)

Page 66, paragraph 34*a,* chart. Add the following after the last item:

Fig. No.	Description
61.3	Servo Motor Assembly S1665–61755–5, part of Automatic Pilot AN/ASN–23 (Modified), wiring diagram.
77.1	Motor Box Assembly S1591–90005, part of Automatic Pilot AN/ASN–23 (Modified), schematic diagram.

Page 67, paragraph 35. Add the following note below the title:

Note. The motor box assembly used with the AN/ASN–23 (Modified) differs slightly from the motor box assembly used with the AN/ASN–23. Refer to figures 77 and 77.1 for the circuit differences.

Page 82, paragraph 36*c*, heading. Change "(fig. 77)" to: (figs. 77 and 77.1).

Page 101, section I. Add the following note below the title.

Note. The removal and replacement instructions in this section apply to Army Model H–34C Helicopters only. Removal and replacement instructions for Automatic Pilot AN/ASN–23 (Modified) are covered in TM 11–1520–203–35.

Page 110, paragraph 46. Add subparagraph *a*.1.

a.1 Inspection, lubrication, assembly, and disassembly instructions for Servo Motor Assembly S1665–61755–5 and assembly and disassembly instructions for Motor Box Assembly S1591–90005 (part of Automatic Pilot AN/ASN–23 (Modified)) are contained in paragraphs 52.1 through 52.6.

Page 119, figure 58. After "Motor box" add: (S1645–61145).

52.1. Inspection of Servo Motor Assembly S1665–61755–5
(Added)

a. Remove scratches, rust, or corrosion with crocus cloth.

b. Replace O-rings and safety wire them.

c. Replace any parts that are obviously damaged or worn or that fail to meet requirements listed in the following chart.

Item No.	Item	Minimum (od)[b]	Maximum (id)[c]
(6), fig. 58.1	Key	0.038	
(7)	Rollpin	0.066	
(8)	Driver		0.065
(9)	Bushing	0.1760	
(14)	Rollpin	0.066	
(16)	Transducer (hole)	0.065	
(38)	Yoke (hole)		0.1880
(39)	Yoke (hole)		0.0635
(41)[a]	Trunnion		
(42)	Shaft (slot)		0.050
(6),[a] fig. 58.2	Shaft and stop assembly.		

[a] Wear allowed: Flash on stops must be stoned off. Reject if the parts jam when driven to the stop position.

[b] Od represents outer diameter (inches).

[c] Id represents inner diameter (inches).

d. Replace mating parts which fail to pass inspection requirements.

***Caution:* Do not replace only one component of a set of mating parts; replace complete set.**

e. Replace damaged wiring.

f. Replace the transducer and servomotor if they have bent shafts, or if they fail to meet the test or inspection requirements.

g. Replace bearings if they are damaged, worn, or do not rotate freely.

52.2. Lubrication
(Added)

Lubrication of the servomotor consists of placing a few drops of Lubricating oil, general purpose, low temperature MIL–L–7870, on shaft and stop assembly, and then blowing oil off with low-pressure, dry compressed air.

52.3. Disassembly of Servo Motor Assembly S1665–61755–5
(figs. 58.1 and 58.2)
(Added)

a. Remove clamp (4, fig. 58.1) by removing screws (5). Carefully remove servomotor (11) and friction drive assembly from the housing assembly.

b. Remove key (6) by removing rollpin (7).

c. Back out driver (8) until it is clear of bushing (9).

d. Carefully remove bushing (9) from servomotor (11) shaft and remove O-ring (10) from bushing.

Note. If the plug (13) is damaged, remove it from the cabling by disconnecting the endbell (12).

e. Remove rollpin (14) that secures transducer shaft to yoke (38).

f. Carefully remove transducer (16) from bracket and yoke.

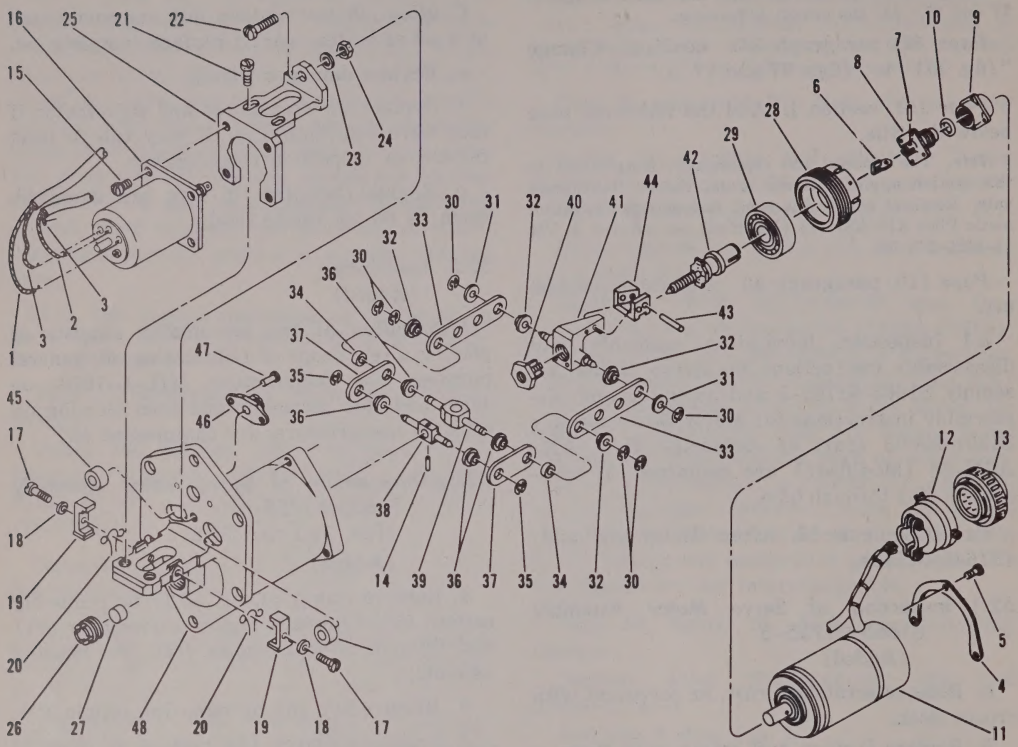
g. Unscrew and remove clamps (19) and springs (20).

h. Remove transducer bracket (25) from housing assembly.

Note. The bearing retainer (26) and housing (48) are a matched set and should be kept together.

***Caution:* Use extreme caution when removing the bearings as they are very delicate.**

i. Remove retainer (28) and bearing (29) along with shaft and stop assembly (6, fig.



1	Wire	13	Plug	25	Transducer bracket	37	Link assembly
2	Wire	14	Rollpin	26	Bearing retainer	38	Yoke
3	Wire	15	Screw	27	Bearing	39	Yoke
4	Clamp	16	Transducer	28	Retainer	40	Adjusting plug
5	Screw	17	Screw	29	Bearing	41	Trunnion
6	Key	18	Washer	30	Retainer ring	42	Shaft
7	Rollpin	19	Clamp	31	Washer	43	Rollpin
8	Driver	20	Spring	32	Bearing	44	Stop
9	Bushing	21	Screw	33	Arm	45	Grommet
10	O-ring	22	Screw	34	Spacer	46	Anchor nut
11	Servomotor	23	Washer	35	Retainer ring	47	Rivet
12	Endbell	24	Nut	36	Bearing	48	Housing

Figure 58.1. (Added) *Servo Motor Assembly S1665–61755–5, exploded view.*

58.2), arm assembly (5), and link assembly (4).

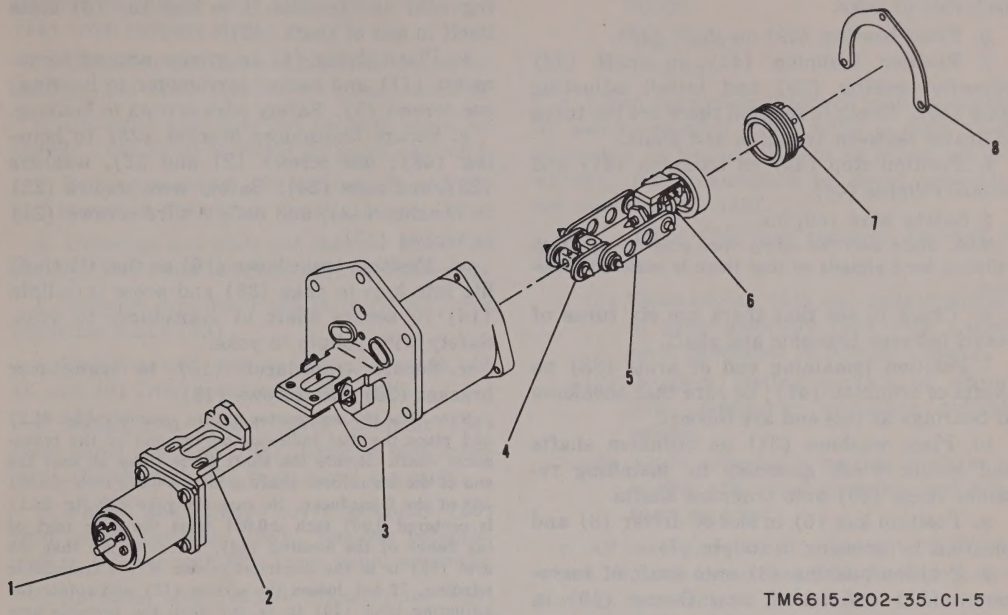
j. Remove retainer ring (30, fig. 58.1) from each side of shaft of yoke (39), and remove washers (31) and retainer rings (30) from trunnion (41).

Note. Carefully slide each arm assembly off the shafts of the yoke and trunnion; be careful not to damage the bearings. The arms (33) are matched sets and must be kept together.

k. Remove spacer (34) from shaft of yoke (39).

l. Remove retainer rings (35) from shaft of yoke (38).

Note. Carefully slide each link assembly off the shafts of the yokes (38 and 39). The link assemblies are matched sets and must be kept together.



1 Transducer
2 Transducer bracket
3 Housing
4 Link assembly
5 Arm assembly
6 Shaft and stop assembly
7 Bearing retainer
8 Clamp

Figure 58.2. (Added) *Servo Motor Assembly S1665–61755–5, mechanical linkage.*

m. Remove bearings (36) from each link assembly (37).

n. Remove the adjusting plug (40) from trunnion (41) and shaft (42).

Note. The adjusting plug, trunnion, and shaft are a matched set and should be kept together.

o. Remove rollpins (43) and stop (44) from trunnion (41).

p. Remove grommets (45) from housing (48).

q. Remove anchor nut (46) from housing (48) by removing rivets (47).

52.4. Assembly of Servo Motor Assembly S1665–61755–5

(Added)

A gram indicator, capable of measuring 550.5 grams and the servomotor fixture assembly (fig. 61.2) are required for assembly.

Note. Before reassembly of the servomotor assembly, all bearings in mechanical linkage must be packed with oscillating bearing grease (MIL–G–25537).

Caution: **Use extreme care when installing bearings. Do not handle bearings with bare hands.**

a. Press bearing (27, fig. 58.1) into retainer (28) and thread retainer into housing (48).

b. Install grommets (45) in housing (48).

c. Place link assembly (37) on each side of yoke (39).

Note. Shoulder of bearings (36) must be inboard when link assembly is placed on yoke (39).

d. Place spacers (34) on shafts of yoke (39).

e. Place arms (33) on shafts of yoke (39).

Note. The shoulder of the two remaining bearings (32) must be outboard when the arm (33) is placed on the shafts of the yoke (39).

f. Position yokes (38 and 39) into link assembly (37) and secure yoke by installing retainer rings (35) on each side of yoke. Secure

yoke (39) by installing retainer rings (30) on each side of yoke.

g. Press bearing (29) on shaft (42).

h. Position trunnion (41) on shaft (42) opposite bearing (29) and install adjusting plug (40). Check to see that there are ten turns of travel between trunnion and shaft.

i. Position stop (44) on trunnion (41) and install rollpins (43).

j. Safety wire rollpins.

Note. Make sure the safety wire goes through both rollpins; bend pigtails so that there is sufficient clearance.

k. Check to see that there are six turns of travel between trunnion and shaft.

l. Position remaining end of arms (33) on shafts of trunnion (41); be sure that shoulders of bearings at this end are inboard.

m. Place washers (31) on trunnion shafts and secure whole assembly by installing retainer rings (30) onto trunnion shafts.

n. Position key (6) in slot of driver (8) and secure it by pressing in rollpin (7).

o. Position bushing (9) onto shaft of servomotor (11) and install new O-ring (10) in bushing and around servomotor shaft.

p. Thread driver (8) into bushing (9). Driver must be adjusted so that it takes 8 to 30 inch-onuces of torque to move servomotor shaft within O-ring. To obtain 8 to 30 inch-ounces of torque, place a suitable rod through hole in servomotor shaft. Place a gram indicator on key (6). With servomotor secured so it cannot move, hold gram indicator steady and turn servomotor shaft until gram indicator reads 226.8 to 550.5 grams. (One ounce equals 28.35 grams.) Tighten driver, recheck torque value on gram indicator, and safety wire driver to bushing.

q. Slide link assembly (4, fig. 58.2), arm assembly (5), and shaft and stop assembly (6) into rear opening of housing (48, fig. 58.1) and position it so that shaft (42) seats against bearing (27).

r. Thread retainer (28) into housing (48).

s. Position springs (20) and install clamps (19); use screws (17) and washers (18).

Note. Thread bearing retainer (26) in or out to position yoke (39) at an 0.967 inch ±0.001 dimension. Tighten bearing retainer and retainer (28). Shaft (42) should turn freely with a maximum of 0.002-inch end play. Safety wire bearing retainer (26) and retainer (28) to housing (48).

t. Install motor and friction drive into housing (48) and position it so that key (6) seats itself in slot of shaft (42).

u. Place clamp (4) in groove around servomotor (11) and secure servomotor to housing; use screws (5). Safety wire screws to housing.

v. Secure transducer bracket (25) to housing (48); use screws (21 and 22), washers (23), and nuts (24). Safety wire screws (22) to housing (48), and safety wire screws (21) to screws (17).

w. Position transducer (16) so that its shaft fits into hole in yoke (38) and press in rollpin (14) to secure shaft of transducer to yoke. Safety wire rollpin to yoke.

x. Secure transducer (16) to transducer bracket (25); use screws (15).

Note. Use the servomotor fixture assembly (fig. 61.2) and place the dial indicator on the end of the transducer shaft. Rotate the shaft three times so that the end of the transducer shaft is moved 0.075 inch ±0.001 out of the transducer. Be sure the yoke (39, fig. 58.1) is centered 0.967 inch ±0.001 from the rear part of the flange of the housing (48). Check to see that the arm (33) is in the electrical center of the transducer winding. If not, loosen the screws (15) and rotate the adjusting plug (40) in or out until the movable arm of the transducer is centered. Recheck the transducer center and safety wire the adjusting plug to the trunnion to prevent movement in either direction.

y. Install endbell (12) and plug (13).

z. Install grommets (45) into housing (48).

aa. If transflex tubing has been removed from wiring, replace it. Pull wiring through grommets (45) on housing (48) and solder wires (1, 2, and 3) to tranducer. Replace waxed cord that secures wiring to servomotor and transducer.

ab. Use rivets (47) and install anchor nut (46) on housing (48).

52.5. Disassembly of Motor Box Assembly S1591–90005

(fig. 58.3)
(Added)

a. Unfasten and remove cover assembly (1) from panel assembly (98).

Note. All receptacles in motor box assembly are potted. To remove a wire from receptacle, carefully cut and remove all potting from receptable with a sharp knife. Unsolder and remove wire from receptacle. All damaged wire must be replaced.

b. Unfasten and remove amplifier receptacle (4) from support shelf.

c. Unfasten and remove power receptacle

(6), yaw receptacle (8), roll receptacle (10), altitude receptacle (12), and pitch receptacle (14) from support shelf.

d. Unfasten and remove terminal board assembly (16) from brackets on panel assembly.

e. Unfasten and slide out resistor board assembly (18) from brackets on panel assembly.

f. Remove resistors (20 through 29 and 31) and capacitor (30) from resistor board (32).

g. Unfasten and slide out resistor board assembly (33) from brackets on panel assembly.

h. Remove capacitors (35 through 42) from capacitor board (43).

i. Unfasten and remove capacitors (45, 46, 48, and 49) from panel assembly (98).

j. Unbolt and remove cover assembly (54) from panel assembly (98). Remove potentiometers (50 through 53) from panel assembly.

k. Unbolt and remove cover assembly (59) from panel assembly (98). Remove potentiometers (55 through 58) from panel assembly.

l. Unfasten and remove transformer (60) from panel assembly (98).

m. Unbolt and remove magnetic amplifiers (65, 69, 73, and 77) from brackets (63, 67, 71, and 75).

n. If necessary, unfasten and remove brackets (63, 67, 71, and 75) from panel assembly (98).

o. Unfasten and remove motor box panel assembly (78) from panel assembly (98).

p. Unfasten and remove pitch switch (80), altitude switch (81), roll switch (82), yaw switch (83), governor switch (84), and switch (89) from panel assembly (95).

q. Unfasten and remove motor voltage test jacks (85 and 86) from panel assembly (95).

r. Unfasten and remove override check switch (87) from panel assembly (95).

s. Unfasten and remove guard assembly (90). Remove knob (92) and channel selector switch (93) from panel assembly (95).

t. If damaged, remove edging (94) from panel assembly (95).

u. Remove nameplate (96) from panel assembly (98).

52.6. Assembly of Motor Box Assembly S1591–90005

(fig. 58.3)
(Added)

a. Clean nameplate (96) and mating surface of panel assembly (98) with a clean cloth dampened in lacquer thinner or other suitable solvent. Bond nameplate to planel assembly; use adhesive EC–1357.

b. If edging (94) was removed, proceed as follows:

(1) Clean edging (94) and mating surface of panel assembly (95) with a clean cloth dampened in lacquer thinner.

(2) Roughen mating surface of edging with sandpaper or other suitable means.

(3) Apply adhesive to mating surfaces of edging and panel assembly and bond them together.

c. All connectors must be potted after being wired. Sealing compound MIL–S–8516 is in a package consisting of a container of base compound and a container of accelerator. For potting instructions, proceed as follows:

Warning: **Sealing compound contains flammable volatile solvent; keep it away from heat and open flame and use with adequate ventilation. Avoid prolonged breathing of vapor. Avoid prolonged or repeated contact with skin. To prevent skin irritations, rubber gloves or protective hand creams should be used.**

(1) Open accelerator compound container and stir thoroughly with a clean rod or paddle.

(2) Open base compound container and stir thoroughly with a clean rod or paddle.

(3) Pour all accelerator compound into base compound and stir until no reddish particles of accelerator remain undispersed in mixture. Storage life of prepared sealing compound is approximately 4 hours at room temperature. Storage life of sealing compound may be increased by refrigeration. Refrigeration at —10° C. (14° F.) will increase storage life to approximately 48 hours. Refrigerated com-

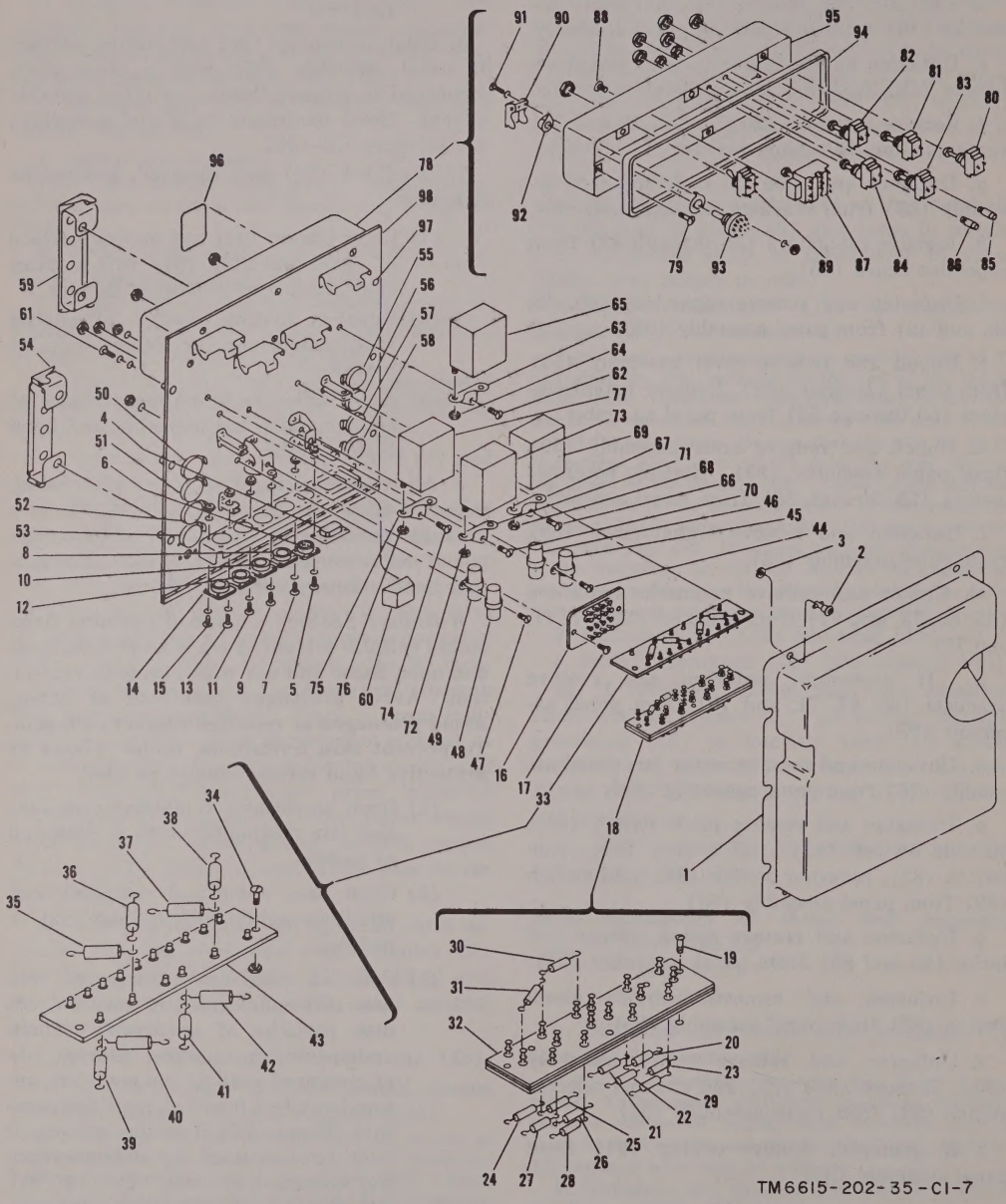


Figure 58.3. (Added) *Motor Box Assembly S1591–90005, exploded view.*

1 Cover assembly
2 Stud
3 Lockwasher
4 Amplifier receptacle
5 Screw, washer, lockwasher, nut
6 Power receptacle
7 Screw, washers, nut
8 Yaw receptacle
9 Screw, washers, nut
10 Roll receptacle
11 Screw, washers, nut
12 Altitude receptacle
13 Screw, washers, nut
14 Pitch receptacle
15 Screw, washers, nut
16 Terminal board assembly
17 Screw
18 Resistor board assembly
19 Screw, nut
20 Resistor
21 Resistor
22 Resistor
23 Resistor
24 Resistor
25 Resistor
26 Resistor
27 Resistor
28 Resistor
29 Resistor
30 Capacitor
31 Resistor
32 Resistor board
33 Resistor board assembly
34 Screw, nut
35 Capacitor
36 Capacitor
37 Capacitor
38 Capacitor
39 Capacitor
40 Capacitor
41 Capacitor
42 Capacitor
43 Capacitor board
44 Screw, washer, nut
45 Capacitor
46 Capacitor
47 Screw, washer, nut
48 Capacitor
49 Capacitor
50 Potentiometer
51 Potentiometer
52 Potentiometer
53 Potentiometer
54 Cover assembly
55 Potentiometer
56 Potentiometer
57 Potentiometer
58 Potentiometer
59 Cover assembly
60 Transformer
61 Screw, washer, lockwasher
62 Screws, nut
63 Bracket
64 Nut
65 Magnetic amplifier
66 Screw, nut
67 Bracket
68 Nut
69 Magnetic amplifier
70 Screw, nut
71 Bracket
72 Nut
73 Magnetic amplifier
74 Screw, nut
75 Bracket
76 Nut
77 Magnetic amplifier
78 Motor box panel assembly
79 Screw
80 Pitch switch
81 Altitude switch
82 Roll switch
83 Yaw switch
84 Governor switch
85 Motor voltage test jack
86 Motor voltage test jack
87 Override check switch
88 Screw
89 Switch
90 Guard assembly
91 Screw, washers, nut
92 Knob
93 Channel selector switch
94 Edging
95 Panel assembly
96 Nameplate
97 Stud
98 Panel assembly

Figure 58.3—Continued.

pound must be warmed to room temperature before use.

(4) Clean connector with solvent and allow at least 5 minutes to dry before potting connector.

(5) Pour sealing compound into mold. Connector should be tapped or vibrated gently while mold is being filled to prevent formation of air pockets in sealing compound. A clean piece of small wooden dowel rod may be used to tamp sealing compound around wires and pins or sockets.

(6) Remove excess compound on outside of connector.

(7) Before applying power to connector, allow the compound to set 24 hours at room temperature for curing. During cold weather, sufficient heat should be provided to maintain connector at approximately 24° C. (75° F.).

Note. Tools and equipment used should be cleaned immediately after use. Sealing compound, which has cured, can be removed with cleaning compound.

d. Install channel selector switch (93) and knob (92) on panel assembly (95). Install guard assembly (90).

e. Secure override check switch (87) to panel assembly (95).

f. Install motor voltage test jacks (85 and 86) on panel assembly (95).

g. Position pitch switch (80), altitude switch

(81), roll switch (82), yaw switch (83), governor switch (84), and switch (89) on panel assembly (95) and fasten in place.

h. If brackets (63, 67, 71, and 75) were removed, secure them to panel assembly (98).

i. Position magnetic amplifiers (65, 69, 73, and 77) on brackets (63, 67, 71, and 75) and bolt in place.

j. Secure transformer (60) to panel assembly (98).

k. Position potentiometers (55 through 58) on panel assembly (98). Position cover assembly (59) over potentiometers and secure in place.

l. Position potentiometers (50 through 53) on panel assembly (98). Position cover assembly (54) over potentiometers and secure in place.

m. Position capacitor (45, 46, 48, and 49) on panel assembly (98) and fasten in place.

n. Position capacitors (35 through 42) on capacitor board (43) and fasten in place.

o. Slide resistor board assembly (33) on brackets on panel assembly (98) and secure in place.

p. Install resistors (20 through 29 and 31) and capacitor (30) on resistor board (32).

Note. The resistance value of resistor pairs (20 and 21, 22 and 23, 24 and 25, 26 and 27, and 28 and 29) must be matched within 1 percent of each other.

q. Slide resistor board assembly (18) on brackets on panel assembly (98) and secure in place.

r. Position terminal board assembly (16) on panel assembly (98) and fasten in place.

s. Position power receptacle (6), yaw receptacle (8), roll receptacle (10), altitude receptacle (12), and pitch receptacle (14) on support shelf and fasten in place.

t. Position amplifier receptacle (4) on support shelf and fasten in place.

u. Position cover assembly (1) on panel assembly (98) and secure in place.

Page 120, section III. Add the following note below the title:

Note. The adjustment procedure for Motor Box Assembly S1591–90005 is covered in TM 11–1520—203–35.

Page 127, chapter 4. Add the following note below the title:

Note. The information in this chapter covers the AN/ASN–23 configuration in Army Model H–34C Helicopters only. System test data concerning the AN/ASN–23 (Modified) configuration in Army Model H–37B Helicopters is contained in TM 11–1520–203–35.

CHAPTER 4.1
FINAL TESTING, SERVO MOTOR ASSEMBLY S1665–61755–5
(Added)

Note. Perform final testing of the servomotor assembly in the *exact sequence* given in paragraphs 62.1 through 62.13.

62.1. Minimum Performance Standards

a. Test Equipment Required. The following chart list the test equipment required for final testing the servomotor assembly.

Nomenclature	Technical manual	Common name
Ohmmeter ZM–21A/U	TM 11–2050	Megger
Servo Motor Test Panel S1670–10426		Servomotor test panel
Voltmeter, Meter ME–30A/U	TM 11–6625–320–12	Voltmeter
Multimeter AN/URM–105	TM 11–6625–203–12	Multimeter
Gram scale, spring-type (capable of measuring 550.5 grams)		Gram scale
Dial indicator with preload of 0.005 inch maximum		Dial indicator

b. Minimum Performance Check Chart. Each servomotor assembly should be checked to determine whether or not it meets the minimum performance requirements listed in the following chart.

Type of check	Minimum test requirement
Winding resistances (fig. 61.3):	
Motor excitation winding (white to yellow), pins C and A.	175 ohms ±20
Generator excitation winding (white to orange), pins C and D.	660 ohms ±60
Motor control winding (white to red) pins C and B.	175 ohms ±20
Generator output winding (blue to brown), pins E and F.	1,000 ohms ±100
Shield to any wire	Infinity
Transducer resistance (fig. 61.3):	
Pins K and H	1,500 to 1,650 ohms
Insulation resistances:	
Wire shield to motor plug endbell.	100 megohms
Wire shield to motor frame	100 megohms
Plug pin to motor frame	10 megohms
Plug pin to motor endbell	100 megohms
Plug pin to wire shield	10 megohms
Any transducer terminal to case	50 megohms
Motor starting voltage:	
No load	3 volts
Mechanical linkage load	15 volts
Motor stall torque:	
8 volts	1.75 inch-grams
25 volts	7.5 inch-grams
75 volts	27.5 inch-grams
Generator null voltage	0.015 volt
Generator output	0.050 volt
Transducer travel	0.150 inch ±0.002

62.2. Preparation for Testing Servomotor Assembly

a. Mount the servomotor assembly on the servomotor checking fixture (fig. 61.1) and adjust the trunnion travel. Mount the servomotor assembly on servomotor fixture assembly (fig. 61.2) and attach the shorting plug of the servomotor test panel to the servomotor assembly receptacle.

b. Measure the insulation of the lead wires with the megger between the lead of the shorting receptacle and each of the following points:

Location	Minimum insulation resistance (megohms)
Motor frame	100
Motor plug endbell	100
Wire shield	100

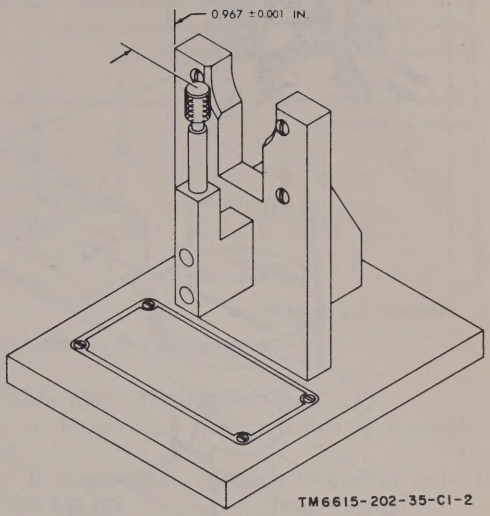


Figure 61.1. Servomotor checking fixture.

c. Remove the shorting receptacle and measure the insulation resistance from the wire shield to the following points:

Location	Minimum insulation resistance (megohms)
Motor frame	100
Motor plug endbell	100

d. Inspect the transducer end cap for dirt, see that solder connections are secure, and that neither terminals nor shaft are bent.

62.3. Servomotor Test Panel Setup

a. Connect the power lead, by means of a cable assembly, to the servomotor test panel and connect the lead to a 155-volt ac and 28-volt dc power source. Check to see that line voltages are maintained at 155 volts ac ±3 and 28 volts dc ±0.5.

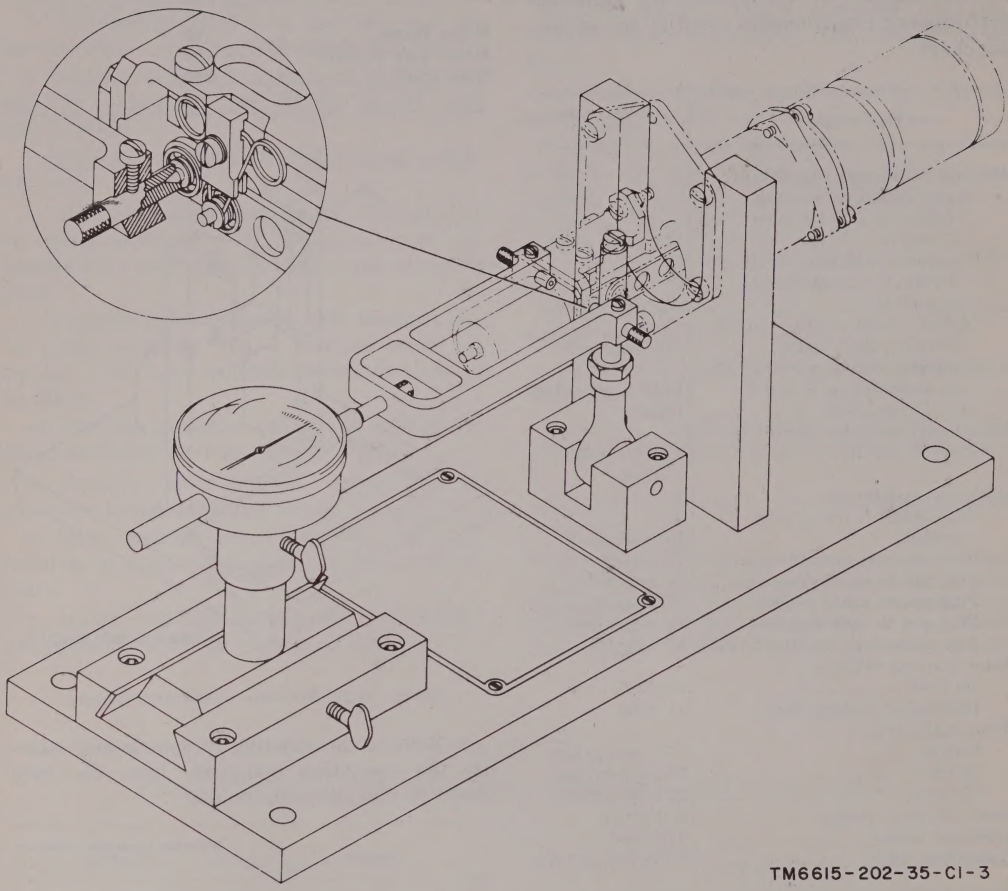


Figure 61.2. Servomotor fixture assembly.

b. Calibrate the servomotor test panel (par. 62.4).

c. Connect the servomotor dummy lead to one of the receptacles on front panel of the servomotor test panel.

d. Run the servomotor assembly from stop to stop; use the servomotor test panel COARSE POSITIONING control. Be sure there is no interference of servomotor travel due to improper adjustment or installation of the servomotor assembly centering springs.

e. Make a careful check at both ends of the servomotor assembly travel with large signal inputs; use the servomotor test panel CYCLING SWITCH in both directions. Make certain that the outer race of the servomotor assembly bearing never turns in excess of 45 rpm.

62.4. Calibration of Servomotor Test Panel

a. Connect the servomotor dummy load to one of the receptacles on the front panel of the servomotor test panel.

b. Place rotary selector switch S2 in position 1.

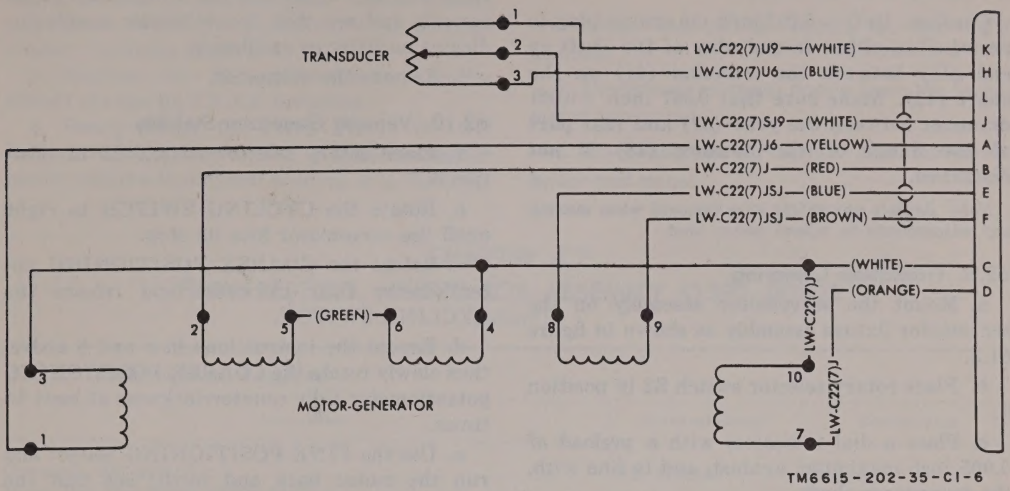


Figure 61.3. Servomotor Assembly S1665–61755–5, wiring diagram.

c. Place the power switch in the ON position and allow a 2 minute warmup period.

d. Move the CYCLING SWITCH from center OFF position to right and left positions.

e. Adjust the INDICATOR BALANCE potentiometer for equal deflections on M1 galvanometer.

f. Rotate the INDICATOR GAIN potentiometer for a deflection of exactly 49 in each direction on M1 galvanometer.

g. Set the FINE POSITIONING helipot at approximately 5 and rotate the VELOCITY GENERATOR EXCITATION potentiometer fully clockwise.

Note. Receptacles on the front panel of the servomotor test panel are marked S1–1, S1–2, and S1–3. Numbers following dash correspond to position of switch S1 which must correspond to receptacle being used.

62.5. Motor Phasing

a. Place rotary selector switch S2 in position 3.

b. Rotate the COARSE POSITIONING potentiometer clockwise. This will enable the servomotor to run and move the transducer shaft away from the motor.

c. Repeat the instructions in *b* above and see that M1 galvanometer needle deflects to the left.

62.6. Motor Starting Voltage

a. Place rotary selector switch S2 in position 3.

b. Connect the voltmeter to binding posts B and LO.

c. Adjust the FINE POSITIONING helipot and COARSE POSITIONING potentiometer slowly and smoothly to cause M1 galvanometer needle to move from zero to either end. Voltage required to run the servomotor should not exceed 10 volts, except for intermittent momentary voltages, up to an additional 10 volts, from center of travel to 0.050 inch of travel. Maximum voltage on last 0.025 inch of travel is 15 volts, except for kicks of an additional 10 volts.

d. Remove the voltmeter.

62.7. Motor Bind

a. Place rotary selector switch S2 in position 3.

b. Run the servomotor from stop to stop; use the FINE POSITIONING helipot. Be sure there are no erratic jumps or oscillations as indicated by M1 galvanometer needle motion.

c. If any binding is evidenced, it may be relieved by loosening the bearing retainer (26, fig. 86) or by loosening the adjusting plug (40) on the shaft (42).

Note. If the adjustment in *c* above does not relieve binding, reject the servomotor.

***Caution:* Only a 0.002-inch maximum play is permissible, either in end play of the shaft or end play between the trunnion (41) on the shaft (42). Make sure that 0.967 inch ±0.001 diameter between the yoke (39) and rear part of the flange of the housing (48) is not disturbed.**

Note. Replace any safety wire removed when making any adjustments to relieve motor bind.

62.8. Transducer Centering

a. Mount the servomotor assembly on the servomotor fixture assembly as shown in figure 61.2.

b. Place rotary selector switch S2 in position 3.

c. Place a dial indicator, with a preload of 0.005 inch maximum, against, and in line with, the transducer shaft.

d. Run the servomotor from stop to stop; use the FINE POSITIONING potentiometer. Transducer travel should be 0.0150 inch ±0.002.

e. Zero M1 galvanometer with the COARSE POSITIONING potentiometer and FINE POSITIONING helipot. The dial indicator should show the transducer arm to be within ±0.001 inch of its center of travel.

f. Place rotary selector switch S2 in position 3.

g. Place CYCLING SWITCH to left and hold it. Place the CYCLING SWITCH to right and hold it. M1 galvanometer should read from 48 to 50 in each direction. Readings should be equal to each other by ±1 M1 galvanometer division.

62.9. O-Ring Slippage

a. Use CYCLING SWITCH and run the servomotor hardover in both directions.

b. Hold the servomotor against each stop for 30 seconds and see that the servomotor shaft does not slip in the O-ring.

Note. Any slippage of the motor shaft within the O-ring may be observed visually by watching the motor shaft extension inside assembly.

c. Place rotary selector switch S2 in position 2.

d. Connect the voltmeter to binding posts A and LO.

e. Hold the CYCLING SWITCH in both right and left directions for a minimum of 30 seconds and see that the voltmeter needle indicates no jitter or oscillation.

f. Remove the voltmeter.

62.10. Velocity Generator Stability

a. Place rotary selector switch S2 in position 3.

b. Rotate the CYCLING SWITCH to right until the servomotor hits its stop.

c. Rotate the COARSE POSITIONING potentiometer fully clockwise and release the CYCLING SWITCH.

d. Repeat the instructions in *a* and *b* above, then slowly rotate the COARSE POSITIONING potentiometer fully counterclockwise at least 15 times.

e. Use the FINE POSITIONING helipot and run the motor back and forth; see that the servomotor rotation is stable.

Note. Loss of velocity generator voltage due to a loose drag cup nut will be evidenced by motor oscillation and inability to eliminate it with the VELOCITY GENERATOR EXCITATION potentiometer.

62.11. Velocity Generator Output

a. Place rotary selector switch S2 in position 2.

b. Connect the voltmeter binding posts A and LO.

c. With the servomotor approximately centered, place the CYCLING SWITCH to right and hold it. The voltmeter should indicate a 5-volt kick, and then drop to approximately 50 millivolts.

d. Repeat the instructions in *c* above; hold the CYCLING SWITCH to left.

e. Remove the voltmeter.

62.12. Servomotor End Play

a. Place rotary selector switch S2 in position 3.

b. Place a dial indicator against, and in line with, the transducer shaft.

c. Push and pull on the yoke at the centerline of the motor assembly with a force of ½ pound. End play should not exceed 0.002 inch as indicated on the dial indicator.

d. Rotate the FINE POSITIONING helipot to 5.

e. Center M1 galvanometer needle by using the COARSE POSITIONING potentiometer, and rotate the FINE POSITIONING potentiometer clockwise from 40 to 60.

f. Position of M1 galvanometer needle should change by 1.5 dial divisions.

g. Slowly return the FINE POSITIONING helipot to 40 and see that M1 galvanometer needle returns to original reading $\pm 1/4$ division.

62.13. Turnoff Procedure

a. Place the power switch in the OFF position.

b. Disconnect external power from the servomotor test panel.

c. Disconnect the servomotor from the servomotor test panel.

CHAPTER 4.2
FINAL TESTING, MOTOR BOX ASSEMBLY S1591–90005
(added)

62.14. Test Equipment Required

Nomenclature	Technical manual	Common name
Ohmmeter ZM–21A/U	TM 11–2050	Megger
Motor Box Test Panel S1670–10422–2		Motor box test panel
Voltmeter, Meter ME–30A/U	TM 11–6625–320–12	Voltmeter
Multimeter AN/URM–105	TM 11–6625–203–12	Multimeter

62.15. Minimum Performance Standards

These checks (pars. 62.19–62.27) consist of performance test procedures to determine whether the motor box assembly will meet acceptable operating standards. These procedures are performed with the motor box test panel and include insulation resistance check and series of operating checks to test the individual motor box circuits. The tests must be performed in the exact sequence given. Parts found to be defective should be checked in accordance with the procedures given for testing potentiometers, transformer T101 and magnetic amplifiers (pars. 62.16, 62.17, and 62.18). To aid in tracing the circuits, refer to figure 77.1.

62.16. Testing Potentiometers R105 Through R107
(fig. 77.1).

a. Connect the multimeter between one end contact and the wiper arm of the potentiometer being tested.

b. Loosen the locknut and rotate the wiper arm shaft through its entire range. Note that the meter movement is smooth with no erratic jumps.

c. Rotate each F.U. NULL potentiometer (R105 through R107) until a reading between 500 and 745 ohms is obtained.

d. Rotate each TACH. GEN. potentiometer (R101 through R104) until a maximum reading between 20k and 30k ohms is obtained.

62.17. Testing Transformer T101
(fig. 77.1)

a. Check the continuity and resistance of the transformer windings by using the multimeter. The correct resistance values are as follows:

Terminals	Resistance (ohms $\pm$ 5%)
1 to 2	310
3 to 4	31
5 to 6	31
7 to 8	31
9 to 10	31

b. All other terminal combinations should show an open circuit.

62.18. Testing Magnetic Amplifiers
(fig. 77.1)

a. Check the continuity of the windings by using the multimeter.

b. Check to determine if the control, input, and output windings are shorted.

Note. The GOV. positions of the motor box CHANNEL SELECTOR switch and the CHANNEL DISENGAGE switch are not connected to the autopilot facility of Army Model H–37B Helicopters which do not include a governor channel. However, these switches are internally connected to the motor box circuitry and are used in the motor box testing procedures when using the motor box test panel.

62.19. Insulation Resistance Test

The insulation resistance test is used to measure the dielectric resistance of the wire insulation of the motor box assembly. Test the insulation resistance as follows:

a. Insert the two shorting plugs, provided with motor box test panel, into their respective receptacles J18 and J19 on the motor box assembly.

***Caution:* To prevent damage to the circuitry, the OVERRIDE CHECK switch must be placed in the center position. In any other position, the megger will indicate a short.**

b. Connect the megger between the indicated points in *c* below for 1 minute.

Note. Insulation resistance should not be less than 50 megohms for each test.

c. Connect the megger leads between J19 shorting plug terminal and the motor box assembly chassis.

d. Rotate the motor box assembly CHANNEL SELECTOR switch through all five positions.

e. Hold the motor box assembly MOTOR POSITION-MOTOR INPUT switch in the MOTOR INPUT position.

f. Repeat the instruction in *d* above.

g. Connect the megger leads between J18 shorting plug terminal and the motor box assembly chassis.

h. Repeat *d* through *e* above.

i. Connect the megger leads between J18 shorting plug terminal and the wire shields in the motor box assembly.

j. Hold the motor box assembly MOTOR POSITION-MOTOR INPUT switch in the MOTOR INPUT position.

k. Rotate the motor box assembly CHANNEL SELECTOR switch through all five positions.

l. Place the motor box assembly MOTOR POSITION-MOTOR INPUT switch at MOTOR POSITION.

***Caution:* With the CHANNEL SELECTOR switch in the ALT. position, the megger will indicate a short. To prevent damage to circuitry, make this test as quickly as possible.**

m. Rotate the motor box assembly CHANNEL SELECTOR switch through all five positions.

n. Insert the megger leads between J18 shorting plug terminal and power ground on the motor box assembly (any pin with a black wire attached to it on either terminal board TB101 or TB103).

***Caution:* With the MOTOR POSITION-MOTOR INPUT switch held in MOTOR INPUT position, the megger will indicate a short. To prevent damage to circuitry, make this test as quickly as possible.**

o. Rotate the motor box assembly CHANNEL SELECTOR switch through all five positions.

p. Disconnect the two shorting plugs from the motor box assembly and remove megger.

62.20. Motor Box Test Panel Setup

a. Connect the motor box test panel receptacles, marked J14 through J19, to their respective receptacles on the motor box assembly; use the cable assemblies supplied with the motor box test panel.

b. Place the ON-OFF switch in the OFF position.

c. Connect the power cable to an external source of 115 volts ac ± 3 and 27.5 volts dc ± 0.5.

d. Place switch S1 in position 10, switch S2 in position 1, and switch S3 in position 1.

Note. The MTR BOX SEL switch should be in the S1645–61120 position.

e. Place the ON-OFF switch in the ON position. Check to see that the ac and dc pilot lamps light. Allow 2 minutes for warmup time.

f. Adjust the BALANCE control for zero reading on M1 galvanometer.

g. Place switch S1 in position 9.

h. Place the motor box assembly CHANNEL SELECTOR switch in GOV. position.

i. Adjust the motor box test panel GAIN control until M1 galvanometer reads 40 to the left.

Note. Do not change the GAIN control setting for remainder of tests.

62.21. TACH. GEN. Potentiometer Test

a. Place the switches on the motor box assembly and motor box test panel in the positions listed in the chart below and read M1 galvanometer as follows:

S1 position	CHANNEL SELECTOR position	CHANNEL DISENGAGE position	M1 indication
1	YAW	ON	40L
2	ROLL	ON	40L
3	PITCH	ON	40L
4	ALT.	ON	40L
9	GOV.	ON	40L

b. Place the motor box assembly CHANNEL SELECTOR switch in the GOV. position.

c. Place the motor box assembly CHANNEL DISENGAGE GOV. switch in the OFF position. M1 galvanometer should return to zero. Return the CHANNEL DISENGAGE GOV. switch back to the ON position.

d. Repeat the instructions in *c* above for yaw, roll, pitch, and altitude channels.

e. Check the TACH. GEN. potentiometer as follows:

S1 position	TACH. GEN. potentiometer	M1 indication
5	Y fully clockwise	40L
5	Y fully counterclockwise	0
6	R fully clockwise	40L
6	R fully counterclockwise	0
7	P fully clockwise	40L
7	P fully counterclockwise	0
8	A fully clockwise	40L
8	A fully counterclockwise	0
9	----------	40L

f. Rotate the TACH. GEN. potentiometers smoothly through their entire range. M1 galvanometer movement should follow smoothly. Check MAG AMP control as follows:

S3 position	MAG AMP CONTROL position
2	Fully clockwise
2	Fully counterclockwise
3	Fully clockwise
3	Fully counterclockwise
4	Fully clockwise
4	Fully counterclockwise
5	Fully clockwise
5	Fully counterclockwise

Note. If M1 galvanometer reads zero when potentiometer is in clockwise position for any one position of CHANNEL SELECTOR switch, excluding GOV. position, check for open wiring. If M1 galvanometer reads less than 40, but not zero, when potentiometer is in clockwise position, replace potentiometer. If M1 galvanometer reads 40 to the right when potentiometer is in clockwise position, reverse potentiometer wiring.

62.22. Continuity Test

a. Rotate switch S1 to position 1.

b. Rotate switch S2 to positions 2 through 9. The CONTINUITY lamp should light for all positions.

c. Place switch S2 in position 10. Place OVERRIDE CHECK switch in right position. The CONTINUITY lamp should light.

Note. Return the OVERRIDE CHECK switch to the center position.

d. Place switch S2 in position 11. Place the OVERRIDE CHECK switch in the left position. The CONTINUITY lamp should light.

Note. Return the OVERRIDE CHECK switch to the center position. If the CONTINUITY lamp does not light for all channels, check the circuit for open wiring.

62.23. Magnetic Amplifier Test

a. Place switch S1 in position 10.

b. Rotate the MAG AMP CONTROL on the motor box test panel fully clockwise and counterclockwise and read the meters as follows:

M1 indication	M2 indication	M3 indication
15 ±3L	7–9	0.9–1.1
15 ±3R	0.9–1.1	7–8
15 ±3L	7–8	0.9–1.1
15 ±3R	0.9–1.1	7–8
15 ±3L	7–8	0.9–1.1
15 ±3R	0.9–1.1	7–8
15 ±3L	7–8	0.9–1.1
15 ±3R	0.9–1.1	7–8

Note. Line voltage must be maintained at 115 volts ac ± 0.3. If meter readings are less than specified for any one channel, check magnetic amplifier wiring. If wiring continuity checks, replace magnetic amplifier.

62.24. Resistor Balance Test

a. Place motor box test panel switch S3 in position 1.

b. Place the motor box test panel F.U. NULL CONTROL-BALANCE switch in the BALANCE position.

c. Place motor box test panel MOTOR POSITION-MOTOR INPUT switch at MOTOR POSITION.

d. Place motor box test panel switch S1 in position 11.

e. Rotate the motor box assembly CHANNEL SELECTOR switch to PITCH, ALT., ROLL, and YAW positions. M1 galvanometer should not deflect more than ±0.5 division from zero in any position.

***Caution:* To prevent damage to M1 galvanometer, do not place the CHANNEL SELECTOR switch in the GOV. position.**

Note. If M1 galvanometer deflects more than ±0.5 division from zero, check the balance resistors on the resistor terminal board.

62.25. F. U. NULL Phasing Test

a. Place motor box test panel switch S1 in position 11.

b. Place the motor box test panel F.U. NULL CONTROL-BALANCE switch in the CONTROL position.

c. Check the followup circuit by using the motor box assembly CHANNEL SELECTOR switch and F.U. NULL potentiometers as follows:

S3 position	CHANNEL SELECTOR switch position	F. U. NULL potentiometer	M1 indication
1	YAW	Y Clockwise	33 ±2L
1	YAW	Y Counterclockwise	34 ±2R
5	YAW	Y Clockwise	36 ±2L
5	YAW	Y Counterclockwise	38 ±2R
1	ROLL	R Counterclockwise	25 ±2R
1	ROLL	R Clockwise	26 ±2L
4	ROLL	R Clockwise	38 ±2L
4	ROLL	R Counterclockwise	37 ±2R
1	PITCH	P Clockwise	26 ±2L
1	PITCH	P Counterclockwise	25 ±2R
3	PITCH	P Clockwise	38 ±2L
3	PITCH	P Counterclockwise	37 ±2R
1	ALT	A Clockwise	38 ±2R
1	ALT	A Counterclockwise	36 ±2L
2	ALT	A Clockwise	38 ±2R
2	ALT	A Counterclockwise	36 ±2L

Note. If M1 galvanometer readings are less than indicated value, or no reading is obtained for any one channel, check wiring and potentiometer.

d. Rotate each F.U. NULL potentiometer through its entire range M1 galvanometer movement should follow smoothly.

Note. Replace any F.U. NULL potentiometer if M1 galvanometer does not move or if movement is erratic.

62.26 Override Check Test

a. Place motor box test panel switch S1 in position 11.

b. Place motor box test panel switch S2 in position 1.

c. Place motor box test panel switch S3 in position 1.

d. Rotate the motor box assembly CHANNEL SELECTOR switch to ALT., YAW, ROLL, and PITCH positions, and adjust associated F.U. NULL potentiometer for a zero reading on M1 galvanometer.

e. Move the motor box assembly OVERRIDE CHECK switch to left. M1 galvanometer should read as follows:

CHANNEL SELECTOR switch position	M1 indication
ALT	35 ±4R
YAW	35 ±4L
ROLL	32 ±4L
PITCH	32 ±4L

f. Place the motor box assembly OVERRIDE CHECK switch to right. M1 galvanometer should read as follows:

CHANNEL SELECTOR switch position	M1 indication
ALT	35 ±4L
YAW	35 ±4R
ROLL	32 ±4R
PITCH	32 ±4R

Note. If M1 galvanometer readings are not as specified, check value of balance resistors, OVERRIDE CHECK switch, and associated wiring.

g. Return the OVERRIDE CHECK switch to the center position.

62.27. Motor Input Test

a. Disconnect the PITCH, ROLL, ALT., and YAW cable assemblies (J14 through J17) from the motor box assembly.

b. Place motor box test panel switch S1 in position 11.

c. Place the motor box test panel F.U. NULL CONTROL-BALANCE switch in the BALLANCE position.

d. Place the motor box test panel MOTOR POSITION-MOTOR INPUT switch in the MOTOR INPUT position.

e. Place the motor box test panel MTR BOX SEL switch in the S1645–61145 position.

f. Rotate the motor box test panel MAG AMP CONTROL fully clockwise.

g. Hold the motor box assembly MOTOR POSITION-MOTOR INPUT switch in the MOTOR INPUT position.

h. Read M1 galvanometer by using the motor box assembly CHANNEL SELECTOR switch and motor box test panel switch S3 as follows:

S3 position	CHANNEL SELECTOR switch position	M1 indicator
2	ALT.	25 ±4R
3	PITCH	25 ±4R
4	ROLL	25 ±4R
5	YAW	25 ±4R

Note. Placing motor box assembly CHANNEL SELECTOR switch to any other position, excluding GOV. position, for any one position of switch S3 will result in a zero indication on M1 galvanometer.

i. Place the motor box assembly CHANNEL SELECTOR switch in GOV. position.

j. Hold the motor box assembly MOTOR POSITION-MOTOR INPUT switch at MOTOR POSITION and place the test panel MOTOR POSITION-MOTOR INPUT and F.U. NULL CONTROL-BALANCE switches in MOTOR INPUT and CONTROL positions. M1 galvanometer should read 40 to ±5 to the right.

k. Connect the voltmeter leads to the MOTOR VOLTAGE TEST jacks on the motor box assembly.

l. With the motor box assembly CHANNEL SELECTOR switch in GOV. position, the voltmeter should read 115 volts ±3.

Note. If meter readings are not as specified, check the value of resistor R138, amplifier winding, and associated wiring.

Page 141, appendix. After the last item, add the following:

TM 11–1520–203–35 Field and Depot Maintenance Manual, Signal Electronic Equipment Configuration Army Model H–37A Helicopters and Automatic Pilot AN/ASN–23 (Modified) Configuration in Army Model H–37B Helicopters.

Figure 77.1. Motor Box Assembly S1591–90005, schematic diagram.
(Located in back of manual)

BY ORDER OF THE SECRETARY OF THE ARMY:

G. H. DECKER,
General, United States Army,
Chief of Staff.

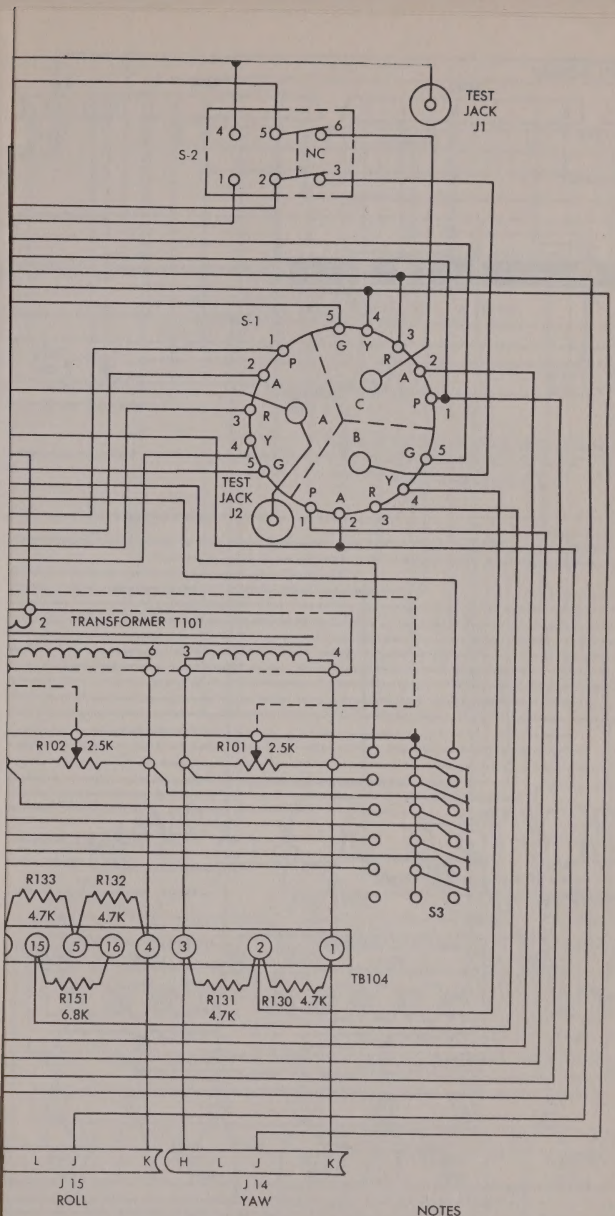
Official:

J. C. LAMBERT,
Major General, United States Army,
The Adjutant General.

Distribution:

To be distributed in accordance with DA Form 12–31 requirements for field maintenance for all Rotor Wing Aircraft.

☆ U. S. GOVERNMENT PRINTING OFFICE: 1962—610509



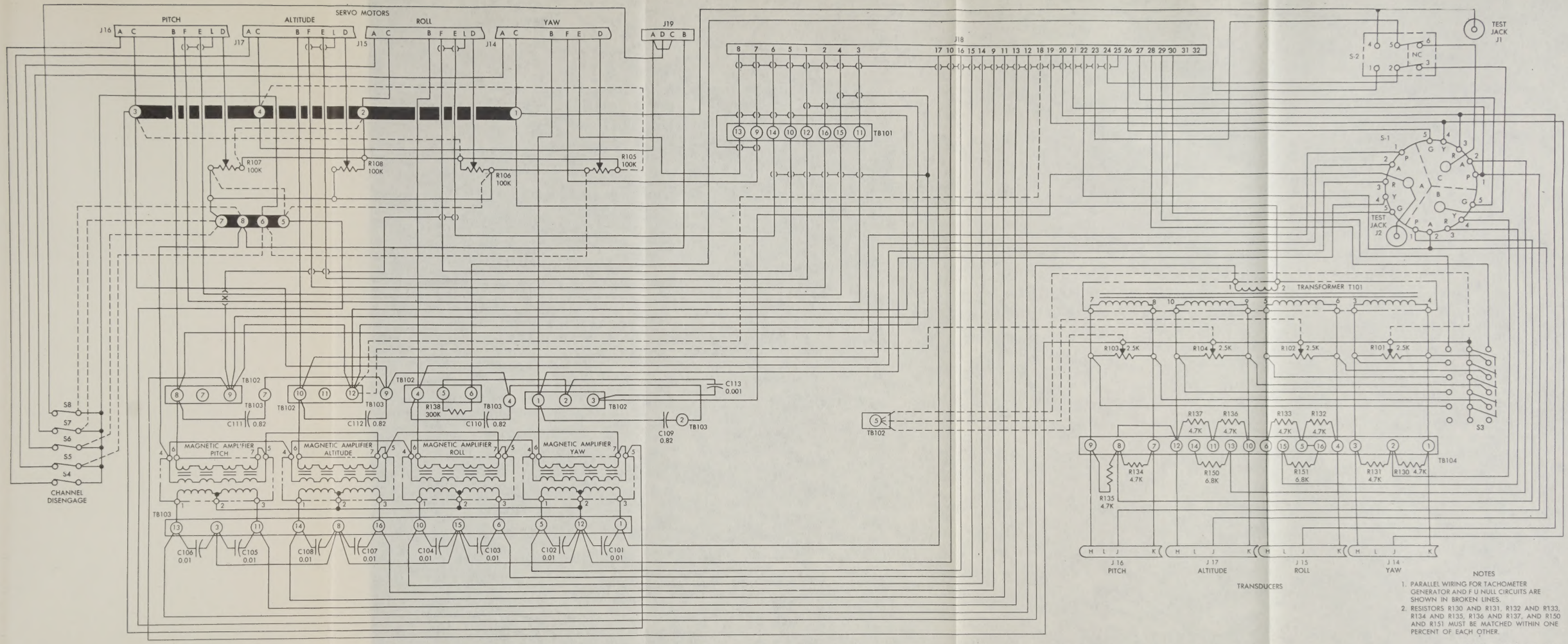
CERS

NOTES

1. PARALLEL WIRING FOR TACHOMETER GENERATOR AND F U NULL CIRCUITS ARE SHOWN IN BROKEN LINES.
2. RESISTORS R130 AND R131, R132 AND R133, R134 AND R135, R136 AND R137, AND R150 AND R151 MUST BE MATCHED WITHIN ONE PERCENT OF EACH OTHER.

TM6615-202-35-CI-I

Figure 77.1



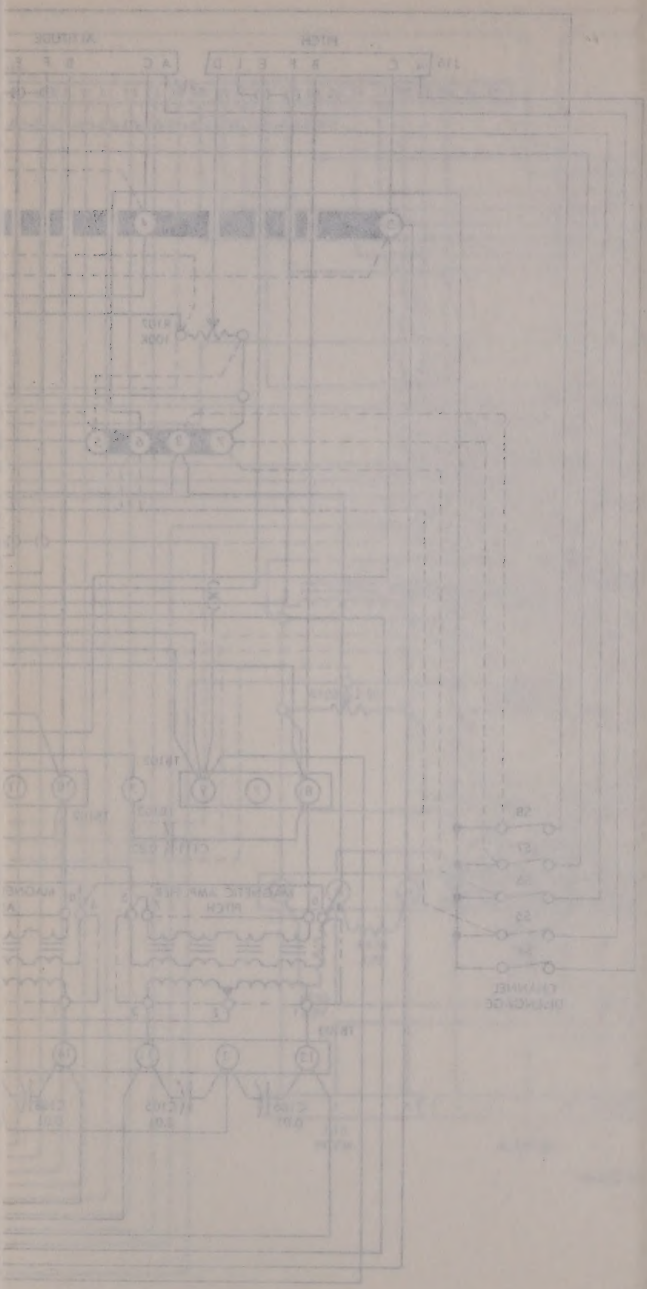
NOTES

1. PARALLEL WIRING FOR TACHOMETER GENERATOR AND F U NULL CIRCUITS ARE SHOWN IN BROKEN LINES.
2. RESISTORS R130 AND R131, R132 AND R133, R134 AND R135, R136 AND R137, AND R150 AND R151 MUST BE MATCHED WITHIN ONE PERCENT OF EACH OTHER.

TM6615-202-35-CI-I

Figure 77.1. Motor Box Assembly S1591–90005, schematic diagram.

Figure 77.1



TECHNICAL MANUAL
No. 11–6615–202–35

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON 25, D. C., *18 January 1960*

AUTOMATIC PILOT AN/ASN–23

		Paragraph	Page
CHAPTER 1.	THEORY		
Section I.	Principles of helicopter flight	1, 2	2
II.	System block diagram analysis	3–7	5
III.	Unit block diagram analysis	8–13	15
IV.	System schematic analysis	14–17	21
V.	Unit schematic analysis	18–23	32
VI.	Flight control switches and external relays, and power distribution circuits	24–27	53
VII.	Mechanical control linkage systems	28, 29	58
CHAPTER 2.	TROUBLESHOOTING		
Section I.	General	30–33	63
II.	System troubleshooting	34–36	66
CHAPTER 3.	REPAIR AND ADJUSTMENTS		
Section I.	Replacement of system components	37–45	101
II.	Repair of system components	46–52	110
III.	Adjustment of system components	53–56	130
CHAPTER 4.	SYSTEM TESTS	57–62	127
CHAPTER 5.	UNPACKING AND PREPARATION FOR SHIPMENT OR LIMITED STORAGE	63, 64	134
APPENDIX	REFERENCES	.....	141
INDEX		.....	142

CHAPTER 1

THEORY

Section I. PRINCIPLES OF HELICOPTER FLIGHT

1. Scope

a. This manual covers field and depot maintenance for Automatic Pilot AN/ASN–23 as installed in Army Helicopter H–34A. It includes instructions to be used by third, fourth, and fifth echelons for troubleshooting, testing, aligning, and repairing the autopilot, replacing maintenance parts, and repairing specified maintenance parts. The instructions do not include maintenance procedures that require the use of special tools, test equipment, and test fixtures.

b. The complete technical manual for this equipment includes two other publications:

TM 11–6615–202–12, Automatic Pilot AN/ASN–23, Operator's and Organizational Maintenance Manual.

TM 11–6615–22–35P, Field and Depot Maintenance Repair Parts and Special Tools List for Automatic Pilot AN/ASN–23.

c. Forward comments concerning this manual to the Commanding Officer, United States Army Signal Publications Agency, Fort Monmouth, N. J.

Note. For applicable forms and records, see paragraph 2, TM 11–6615–202–12.

2. Theory of Helicopter Flight

a. Movement of Main Rotor Blade. The main rotor blades of a helicopter produce lift in fundamentally the same manner as the fixed wings of a conventional aircraft. Lift is caused by the flow of air (relative wind) over an airfoil shape which is inclined at a slight angle (angle of attack) to the air stream (fig. 1). The major difference between the theory of flight of conventional fixed-wing aircraft and rotary-wing aircraft is the method of producing relative wind. In conventional aircraft, relative wind is produced by the forward motion of the airfoil through the atmosphere. The helicopter, however, produces relative wind by rotating the airfoil, and therefore is not dependent on forward motion to produce lift. In addition to rotational motion, the fully articulated motor head permits each blade to *flap* vertically about its horizontal hinge, *hunt* horizontally about its vertical hinge, and also to turn about its span-wise axis to permit *variation of blade angle.*

(1) *Flapping* (fig. 2). The flapping motion of the blades enables the pilot to tilt the rotor cone so as to move the helicopter in any given direction. In forward flight, the blades flap high over the tail and low over the nose, tilting the rotor cone in the direction of flight. The amount of cone tilt is defined as the flapping angle.

(2) *Hunting* (fig. 3). Hunting is the lead or lag of a main rotor blade with respect to its normal radial position. When starting, the blades lag behind their normal radial position, during stopping or autorotation, their inertia causes them to lead the normal radial position.

(3) *Blade angle variation* (fig. 4). During directional flight, the blade angle of each main rotor blade changes constantly to compensate for the variation in the velocity of relative wind. The velocity of relative wind is a function of both the rotational velocity of the blade and the forward velocity of the helicopter. At point A, figure 4, the blade is parallel to the air stream and the forward velocity of the helicopter has no effect. The relative wind over the airfoil is equal to the rotational velocity of the blade. At point B, the blade is traveling directly into the air stream; consequently the relative wind has a velocity equal to the sum of the rotational velocity of the blade and the forward velocity of the helicopter. At point C,

the velocity of the relative wind is again equal to the rotational velocity of the blade. At point D, however, the blade is moving in unison with the air stream and the forward motion of the helicopter tends to cancel the rotational velocity of the blade. Therefore, the velocity of relative wind at point D is the difference between rotational velocity of the blade and the forward velocity of the helicopter. At high forward speeds, the blade tends to lift (stall) in the region near point D, while the blade in the region of point B tends to produce a greater lifting load. To correct this unbalanced condition, the blade angle (angle of attack, fig. 1) is decreased in the region of point B (fig. 4) and increased in the region of point D by tilting the rotor cone in the direction of flight. As the cone tilts forward, the blade angle (with respect to relative wind) remains the same over the nose and tail (points A and C). At point D, however, the blade angle is increased by an amount equal to the degree of tilt, while the blade angle at point B is decreased by the same amount.

b. Forces Acting on Main Rotor Blade. During flight, the rotor blade is subjected to the same forces that act upon the airfoil of any conventional aircraft: namely, lift, weight, thrust, and drag (fig. 1). The summation of these forces is the resultant motive force which propels the helicopter in any direction desired. The magnitude of this motive force and its direction with respect to the chord of the airfoil depends on many other factors such as air density, the shape of the airfoil, and the angle of attack. Centrifugal force also has a great effect on the rotor blades; it limits the flapping action of the blades about their horizontal hinges, and limits the hunting action of the blades about their vertical hinges. It is this force which permits the use of a fully articulated rotor head. The coning angle (fig. 2), which is the average angle made by the blades in their flapping motion, also depends on centrifugal force. As shown in figure 5, the coning angle varies in proportion to the ratio of centrifugal force and the lifting load.

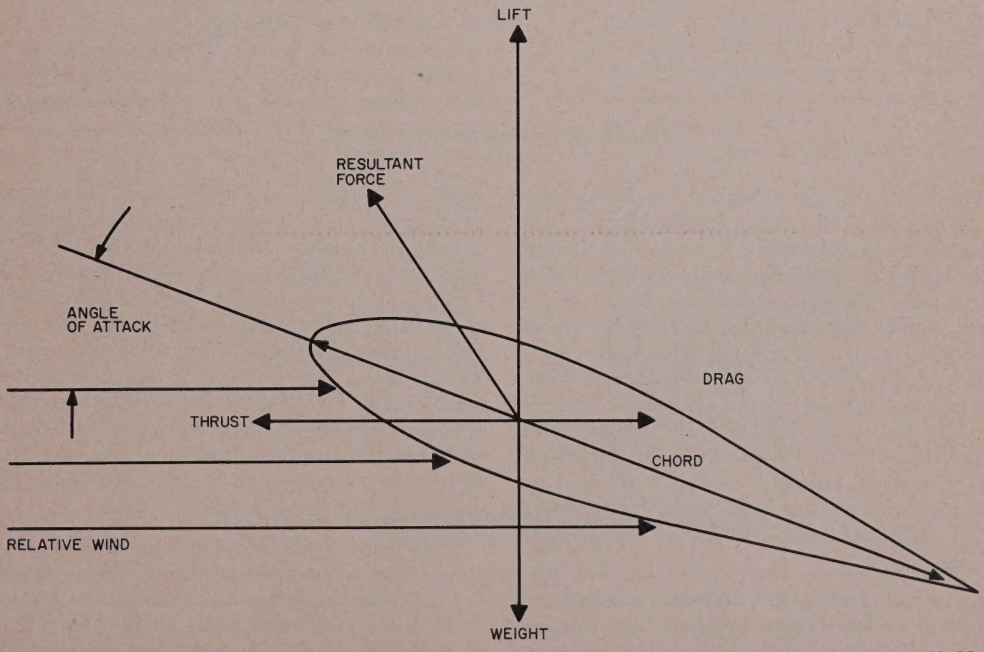


Figure 1. Forces acting on an airfoil.

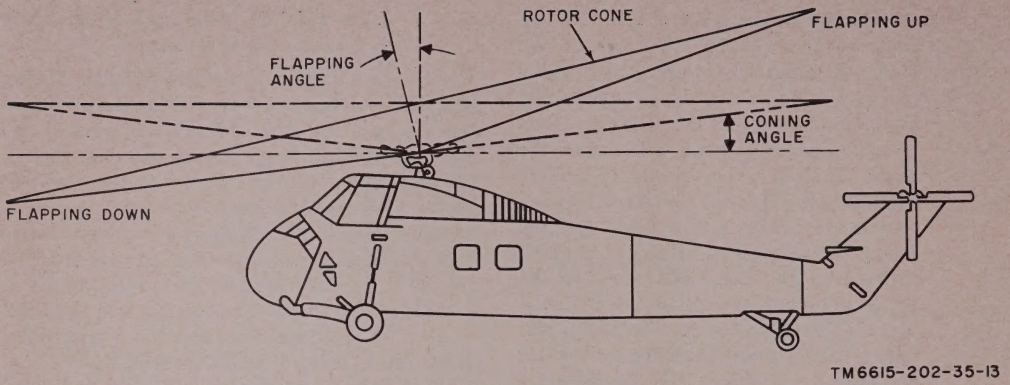


Figure 2. Rotor blade position, forward flight.

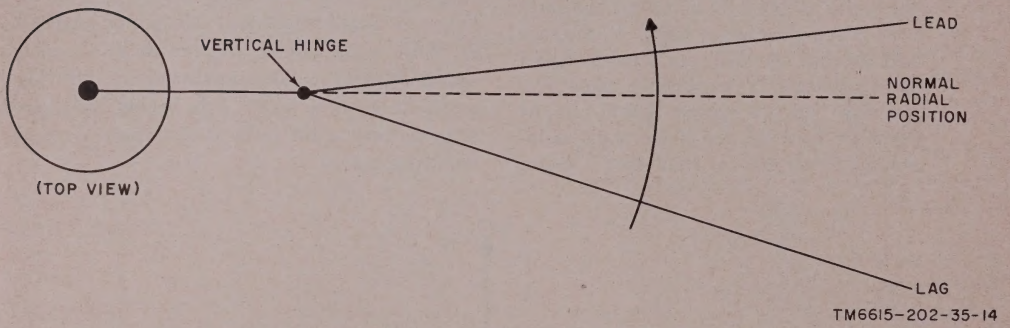


Figure 3. Rotor blade position, hunting.

c. Tail Rotor Blades. The theory of the tail rotor blades is similar to the theory described for the main rotor blades (*a* and *b* above), except that the tail rotor blades are positioned vertically rather than horizontally. The main rotor blades produce torque which tends to rotate the helicopter about its vertical axis. The function of the tail rotor blades is to counteract this torque by producing thrust. When the torque developed by the main rotor blade is equal to the thrust developed by the tail rotor blades, the helicopter will stabilize about its vertical axis. Control of helicopter heading is obtained by increasing or decreasing blade pitch, thereby varying the amount of thrust developed by the tail rotor blades.

d. Automatic Pilot AN/ASN–23. Whereas the conventional fixed-wing aircraft is an inherent stable configuration which tends to hold a level attitude during flight, the helicopter is inherently unstable and requires continual control adjustment and trim corrections in order to maintain the desired altitude and heading. Automatic Pilot AN/ASN–23 is an electromechanical system which improves the handling characteristics of the helicopter by introducing static and dynamic stability, and also provides automatic controlled flight at cruising speed. Through an electronic system of error sensing and amplification, the autopilot applies correction signals to servo motors to actuate the helicopter flight control system so as to control the movement of the rotor blades to maintain stable flight. The autopilot operates in four modes as follows:

(1) *Yaw.* A directional gyro, which is part of the J2 compass system in the aircraft, senses any deviation in heading and applies a displacement signal to the yaw servo motor to aline the helicopter with the heading established by the pilot. This displace-

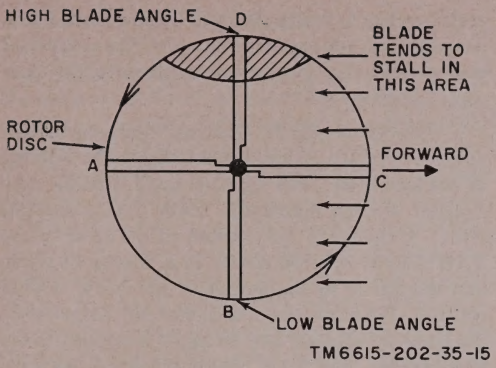


Figure 4. Blade angle variation, forward flight.

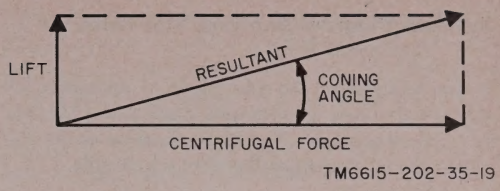


Figure 5. Forces acting on rotor blade.

ment signal is interrupted when the tail rotor control pedals are operated, enabling the pilot to override the autopilot and change heading without disengaging the system. When the pilot removes his feet from the tail rotor control pedals, the autopilot will again trim the tail rotor controls to hold the helicopter on a fixed heading.

(2) *Pitch and roll.* A vertical gyro assembly provides a reference for the pitch and roll modes. The gyro senses any deviation in pitch and roll and applies displacement signals through the pitch servo amplifier assembly and the roll servo amplifier assembly to the pitch and roll servo motors. The servo motors actuate the main rotor linkage to change the cyclic pitch and align the helicopter with the attitude established by the pilot. (These corrections in attitude are limited to 20 per cent of full cylic pitch travel.) At any time during flight, the pilot may override the autopilot input and establish a new attitude reference by repositioning the cyclic control stick. When the helicopter starts to change its attitude in accordance with operation of the cyclic control stick, a displacement signal is generated by the vertical gyro assembly. Operation of the cyclic control stick, however, also drives the pitch and/or roll canceller by means of a mechanical linkage. A pitch and/or roll canceller signal is developed which cancels the displacement signal generated by the vertical gyro assembly, and thereby enables the pilot to change the attitude of the helicopter without disengaging the autopilot. Whenever the pilot positions the cyclic control stick, he establishes a new fixed attitude for the pitch and roll axes; a stick-centering device then holds the cyclic control stick in the desired position.

(3) *Altitude.* A barometric altitude control provides a reference for the altitude mode. When the pilot engages the altitude mode, the altitude control senses any variation in barometric pressure and applies a correction signal to the altitude servo motor. The altitude servo motor actuates the main rotor linkage to change collective pitch. (These corrections are limited to 20 per cent of full collective pitch travel.) Once the altitude mode is engaged, the helicopter will maintain the selected altitude. Since there is no electrical means of cancelling a displacement signal which would develop when the pilot changes from the established altitude, the pilot must disengage the altitude mode, change altitude, and then reengage the altitude mode.

Section II. SYSTEM BLOCK DIAGRAM ANALYSIS

3. General

Automatic Pilot AN/ASN-23 is described in block diagram form in terms of individual mode analyses rather than an overall system analysis. The pitch, roll, altitude, and yaw mode analyses are given in paragraphs 4 through 7. The overall system block diagram (fig. 65) is provided for reference to see the over-all relationship of all system components with each other.

4. Block Diagram Analysis, Yaw Mode
(figs. 6 and 7)

The analysis of the yaw mode of operation includes only those circuits used when a new heading is to be established. The block diagram shows the elements and signal flow for the turn circuits.

a. Turn Circuits (fig. 6). When the pilot or copilot actuates the right or left pedal to turn the helicopter, the +28-volt direct current (DC) line input to yaw transfer relay K2 and synch turn relay K5 is interrupted, de-energizing the two relays. The contacts of K5 apply the output of the power amplifiers to the motor in the yaw synchronizer assembly; the contacts of K2 transfer the rotor output of the yaw synchro to the resistance network of the turn circuits. The yaw synchro output is mixed with the signal from phase reference transformer T1, which is also applied to the resistance network. The combined signal is applied to turn motor VEL. GEN. QUAD. potentiometer R603. The yaw synchronizer assembly generator voltage is applied, in series with the voltage across the turn motor VEL. GEN. QUAD. potentiometer, to the input of turn preamplifier V303A. The signal applied to the turn preamplifier is the result of comparing the signal from the yaw synchro to the reference signal supplied by phase reference transformer T1. The signal from the generator in the yaw synchronizer assembly represents the position of the helicopter prior to the change in heading. Since, in effect, the generator signal is the zero to which both the reference signal from T1 and the signal from the yaw synchro are compared, the generator signal must be applied to the turn amplifier input as the zero reference. Thus the motor continues to rotate as long as the input from the yaw synchro continues to change (reflecting the continued change in the helicopter heading), producing a difference signal as a result of comparison with the output from the resistance network. When the helicopter heading is stabilized, the output from the yaw synchro motor no longer changes, the voltages are balanced, and the motor no longer rotates. When the pilot or copilot releases the foot pedals, the +28-volt dc voltage is reapplied to relays K2 and K5. The output of the yaw synchro rotor is applied to the yaw servo amplifier input through the contacts of K2; the contacts of engage relay K3 open the path from the output of power amplifier output transformer T8 to the motor. The yaw synchro rotor (which is mechanically coupled to the motor generator and turns only when the aircraft heading is being changed) is now turned to a position representing the heading of the aircraft J2 compass system, and is synchronized to the helicopter heading.

b. Yaw Mode (fig. 7). The yaw displacement signal from the J2 compass system reflects the heading of the helicopter. The signal is applied to the yaw synchro through differential YAW TRIM synchro B101. A change in the position of the rotor of the YAW TRIM synchro results in a change of phase and amplitude in the output of the YAW TRIM synchro. When properly positioned, the output from the rotor is balanced, and no signal is applied to the yaw synchro. The YAW TRIM synchro is provided so that small accurate heading adjustments are possible without disengaging the yaw channel. The yaw synchro in the yaw synchronizer assembly converts the three-phase displacement signal from the YAW TRIM synchro to a single-phase signal for application through the contacts of yaw transfer relay K2 to the yaw servo amplifier. Because the rotor of the yaw synchro has been synchronized (*a* above), the signal applied to the yaw servo amplifier has the proper phase and amplitude, reflecting the heading signal generated by the J2 compass system. The same signal is also applied to YAW RATE potentiometer R502. The signal from R502 (which represents the rate of change in the amplitude of the yaw signal) is applied to rate preamplifier V401A. The output signal from displacement preamplifier V401B is applied to mixer-discriminator V403. The signal amplified by V401A is applied to the input of rate discriminator V402. Rate discriminator V402 has both of its input circuits paralleled and as a result both halves of V402 are driven by the output signal from V401A. The output signals from V402 are mixed with the output signal from V401B and applied to inputs of mixer-discriminator V403. The output of V403 is applied to push-pull, parallel power amplifiers V404 and V405. The output from V404 and V405 drives the yaw magnetic amplifier, which in turn provides the driving energy for the yaw servo motor. The yaw servo motor is driven in the direction and for a length of time that corresponds to the phase and magnitude of the original change of helicopter heading signal. The yaw servo motor is mechanically coupled to the yaw tachometer generator and the yaw transducer. YAW DISPL FEEDBACK potentiometer R503 also receives the signal from the yaw transducer. The yaw tachometer generator is connected to the 115-volt, 400-cycle,

phase A line and, together with the signal return current from V401B (combined with the transducer feed-back signal), produces a torque in the tachometer generator. Since the transducer, the tachometer generator, and the servo motor are mechanically coupled, the initial motor rotation produces a signal in the transducer which represents the rate of motor movement and total distance of motor rotation. The resultant net current and the displacement signal through the tachometer generator winding produce a torque in the tachometer generator opposite to the direction of servo motor rotation. This negative feed-back loop action dampens overshoot of the servo motor to prevent motor hunting. In addition, the transducer output provides a signal to return the servo motor to its zero (or center) position. As long as the servo motor is off center, the transducer will also be off its zero setting and will apply a driving signal to the servo motor. When the servo motor reaches zero position (center position), the transducer output is zero, and servo motor rotation stops. With the servo motor at its center position, the servo system can now respond evenly to changes in helicopter heading. The signal for the transducer is obtained from transducer transformer T101, which applies the signal to the transducer in parallel with yaw divider resistors R130 and R131. The yaw divider provides the ground or zero reference for the transducer. The feed-back signal return for displacement preamplifier V401B is through YAW DISPL potentiometer R501, crossfeed potentiometer R25, one winding of the yaw tachometer generator, and through YAW DISPL FEEDBACK potentiometer R503.

c. Phase A, 115-volt, 400-cycle Line. The phase A, 115-volt, 400-cycle line supplies operating potentials for yaw servo amplifier tubes V402 through V405, yaw magnetic amplifier, yaw servo motor, yaw tachometer generator (as explained in *b* above), yaw motor generator, and transducer transformer T101.

5. Block Diagram Analysis, Pitch Mode (fig. 8)

The pitch mode differs from the yaw and roll modes in the input circuit and the path by which the feed-back signal from displacement preamplifier V201B is returned to the pitch tachometer generator.

a. Input Circuit. Vertical gyro B111 in the vertical gyro assembly senses any pitch change from level flight of the helicopter, and mechanically positions the rotor of pitch synchro B113. Any change from the level (or zero) position produces an error signal output from the pitch synchro. The pitch synchro signal is applied to the pitch bridge comprised of resistors R33, and R35 through R37, and potentiometer R34. The output of the bridge is a single-phase signal which is reduced in amplitude and applied to displacement preamplifier V201B and PITCH RATE potentiometer R508.

b. Pitch Servo Amplifier. The output signal from displacement preamplifier V201B is applied to mixer-discriminator V203. The output signal from PITCH RATE potentiometer R508 is applied to rate preamplifier V201A. The signal amplified by V201A is applied to the input of rate discriminator V202. Rate discriminator V202 has both of its input circuits paralleled and, as a result, both halves of V202 are driven by the output signal from V201A. The output signals from V202 are mixed with the output signal from V201B and applied to inputs of mixer-discriminator V203. The output of V203 is applied to push-pull, parallel power amplifiers V204 and V205. The output from V204 and V205 drives the pitch magnetic amplifier, which in turn provides the driving energy for the pitch servo motor. The servo motor is driven in the direction and for a length of time that corresponds to the phase and magnitude of the original change of helicopter pitch signal. The pitch servo motor is mechanically coupled to the pitch tachometer generator and the pitch transducer. The feed-back signal return for pitch displacement preamplifier V201B is through PITCH DISPL FEEDBACK potentiometer R509, one winding of the pitch tachometer generator, C G TRIM control B102, and PITCH DISPL potentiometer R507. The signal from the pitch canceller is combined with the feed-back signal through the C G TRIM and pitch canceller common connections. PITCH DISPL FEEDBACK potentiometer R509 also receives the signal from the pitch transducer. The pitch tachometer generator has its other winding connected to the 115-volt, 400-cycle, phase A line, and together with the signal return current from V201B (combined with the transducer feed-back signal), produces a torque in the tachometer generator. Since the transducer, the tachometer generator, and the servo motor are mechanically coupled, the initial motor rotation produces a signal in the transducer which represents the rate of motor movement and total distance of motor rotation. The resultant net current and the displacement signal

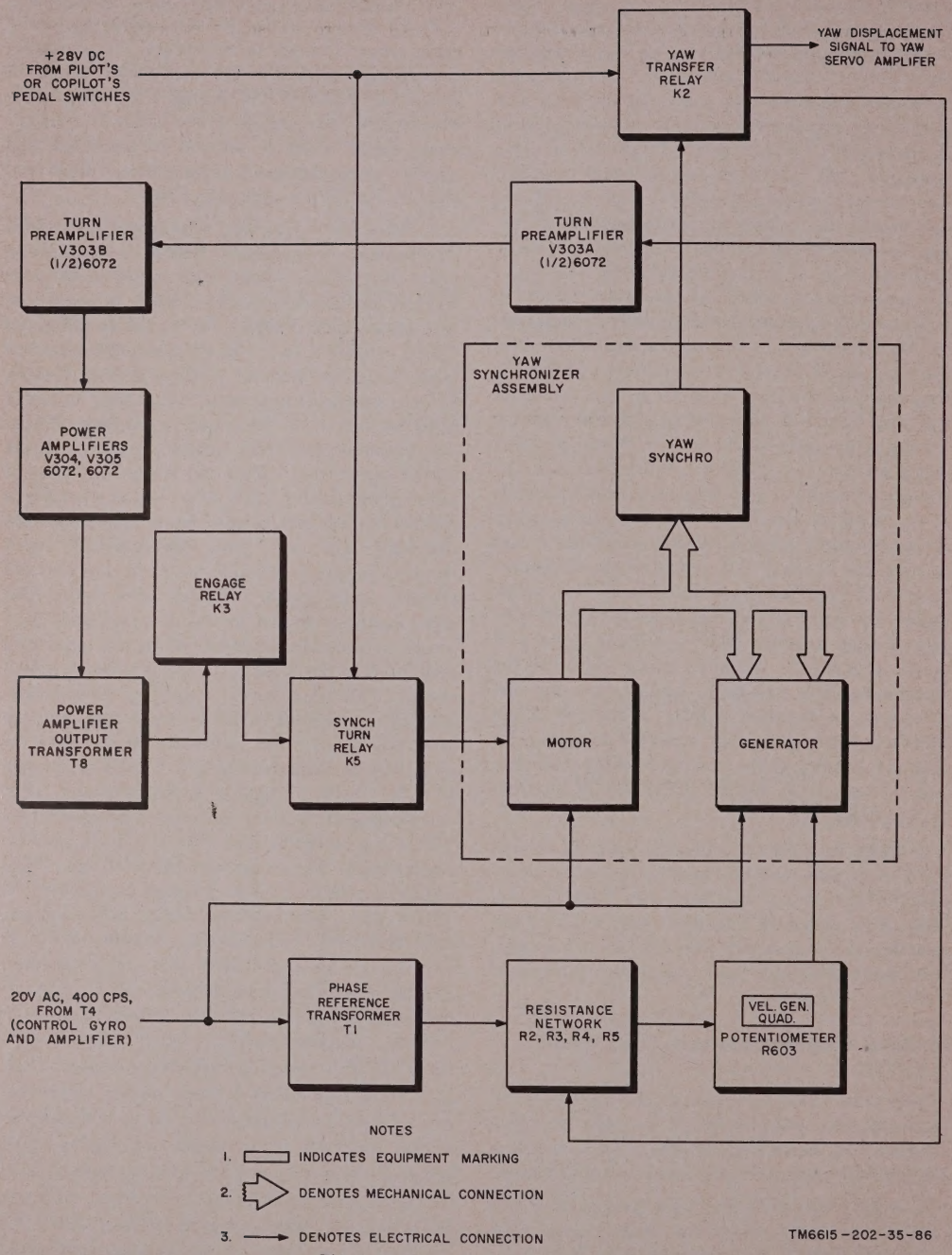


Figure 6. Turn circuit, block diagram.

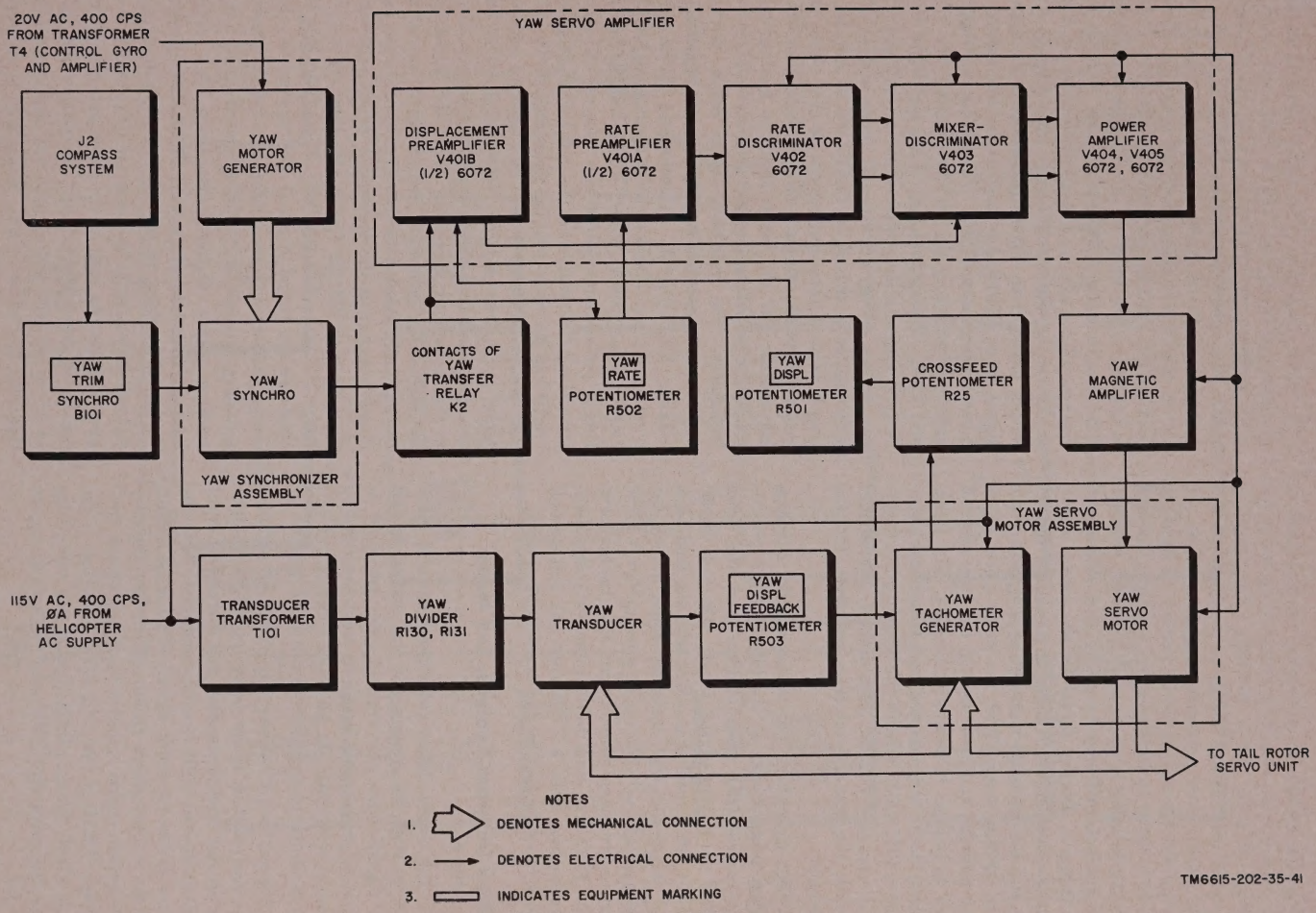


Figure 7. Yaw mode, block diagram.

through the tachometer generator winding produce a torque in the tachometer generator opposite to the direction of servo motor rotation. This negative feed-back loop action dampens overshoot of the servo motor, thus preventing motor hunting. In addition, the transducer output provides a signal to return the servo motor to its zero position. As long as the servo motor is off the center, or zero, position, the transducer will also be off its zero setting and will apply a driving signal to the servo motor. When the servo motor reaches zero position (center position) the transducer output is zero, and servo motor rotation stops. With the servo motor at its center position, the servo system can now respond evenly to changes in helicopter heading. The signal for the transducer is obtained from transducer transformer T101, which applies the signal to the transducer in parallel with the pitch divider. The divider provides the ground or zero reference for the transducer.

c. Pitch Canceller. The pitch canceller develops a signal proportional to the pilot's (or copilot's) cyclic control stick position (fore and aft) from neutral. A portion of the 1-volt, 400-cycle signal applied to the cancellor is mixed with the feed-back signal. Since the pitch canceller signal follows the signal applied to displacement preamplifier V201B, the canceller signal cancels out the displacement signal. With zero input to the pitch servo amplifier, the servo loop does not function and full control authority is exercised by the cyclic control stick.

6. Block Diagram Analysis, Roll Mode

(fig. 9)

The roll mode differs from the yaw and pitch modes in that the response of the system to roll error signals from the vertical gyro assembly is delayed to prevent the autopilot from contributing to ground resonance. In all other respects, the roll mode is similar in operation to the other modes.

a. Input Circuit. When the pilot's or copilot's cyclic control stick is not being moved, the output from the roll canceller is zero, and there is no input to roll integrator V301 from the canceller. With the absence of the canceller signal, there is no output from the roll integrator circuit. Therefore, the only displacement signal applied to displacement preamplifier V201B in the roll servo amplifier is the output of roll Synchro B121 through the roll bridge circuit, roll integrator V301, and contacts of engage relay K4.

b. Servo Amplifier. The signal applied to displacement preamplifier V201B from roll synchro B121 is also applied to ROLL RATE potentiometer R505. The output signal from V201B is applied to mixer-discriminator V203. The output signal from ROLL RATE potentiometer R505 is applied to rate preamplifier V201A. The signal amplified by V201A is applied to the input of rate discriminator V202. Rate discriminator V202 has both of its input circuits paralleled and, as a result, both halves of V202 are driven by the output signal from V201A. The output signal from V202 together with the output signal from V201B are applied to the inputs of mixer-discriminator V203. The output of V203 is applied to push-pull, parallel power amplifiers V204 and V205. The outputs from V204 and V205 drive the roll magnetic amplifier, which in turn provides the driving energy for the roll servo motor. The servo motor is driven in the direction and for a length of time that corresponds to the phase and magnitude of the original change of helicopter heading signal. The roll servo motor is mechanically coupled to the roll tachometer generator and the roll transducer. The feed-back signal return for roll displacement preamplifier V201B is through ROLL DISPL FEEDBACK potentiometer R506, one winding of the roll tachometer generator, and ROLL DISPL potentiometer R504. ROLL DISPL FEEDBACK potentiometer R506 also receives the signal from the roll transducer. The roll tachometer generator has its other winding connected to the 115-volt, 400-cycle, phase A line, and together with the signal return current from V201B (combined with the transducer feed-back signal), produces a torque in the tachometer generator. Since the transducer, the tachometer generator, and the servo motor are mechanically coupled, the initial motor rotation produces a signal in the transducer which represents the rate of motor movement and total distance of motor rotation. The resultant net current and the displacement signal through the tachometer generator winding produce a torque in the tachometer generator opposite to the direction of servo motor rotation. This negative feed-back loop action dampens overshoot of the servo motor, thus preventing motor hunting. In addition, the transducer output provides a signal to return the servo motor to its zero position. As long as the servo motor is off the center, or zero position, the transducer will also be off of its zero setting and will apply a driving signal to the servo motor. When the servo motor

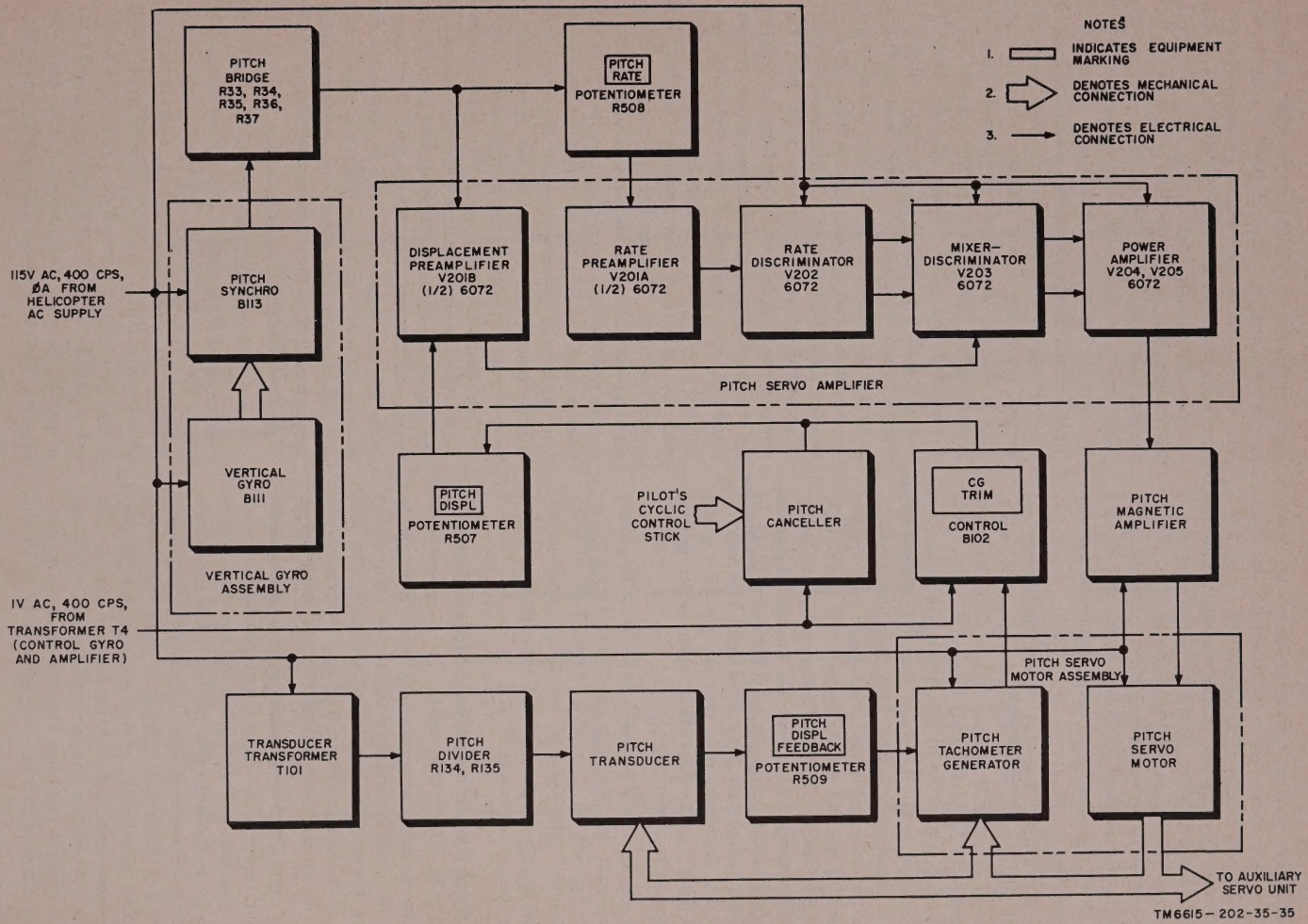


Figure 8. Pitch mode, block diagram.

reaches zero position (center position), the transducer output is zero, and servo motor rotation stops. With the servo motor at its center position, the servo system can now respond evenly to changes in helicopter heading. The signal for the transducer is obtained from transducer transformer T101, which applies the signal to the transducer in parallel with roll divider resistors R132 and R133. The divider provides the ground or zero reference for the transducer.

c. Lag Circuit Engaged. When the pilot or co-pilot initiates a turn using the cyclic control stick, the roll canceller is actuated and a signal from the canceller is applied to roll integrator V301. This signal mixes with the 20-volt, 400-cps reference signal applied to the integrator from transformer T4, and a signal appears at the integrator output circuit. This output signal in turn is combined in the output circuit of the roll integrator with the signal from the roll synchro. The resultant signal is applied to V201B through engage relay K4. This signal lags the original signal developed by roll synchro B121 in the vertical gyro assembly. This lag in loop response prevents the system from responding rapidly to the helicopter oscillations which occur when ground resonance is present.

d. Phase A, 115-volt, 400-cycle Line. The phase A, 115-volt, 400-cycle line supplies operating potentials for roll servo amplifier tubes V202 through V205, the roll magnetic amplifier, servo motor, tachometer generator, and roll motor generator, and transducer transformer T101.

7. Block Diagram Analysis, Altitude Mode (fig. 10)

The operation of the altitude mode is similar to the other modes, the only differences being in the input circuits, the manner of connecting the rate signal to the rate preamplifier, and the return path for the displacement preamplifier feed-back signal.

a. Input Circuit. The altitude control in the helicopter responds to changes in barometric pressure and furnishes a displacement signal which reflects changes in the helicopter altitude. The barometric sensing (pressure-sensitive) element in the altitude control is connected, through a clutch, to a rotor element which picks off a portion of the 30-volt, 400-cycle signal applied to the altitude control. The clutch permits the pilot or copilot to disengage the rotor element from the pressure-sensitive element when changing to a new altitude setting. With the clutch disengaged, the rotor element returns to its normal zero setting. When changes in altitude are desired, the pilot or copilot must disengage the altitude mode by depressing the BAR ALT OFF switch on the control panel, de-energizing relay K7. With K7 de-energized, the clutch in the altitude control is disengaged from altitude preamplifier V2, and the signal line to engage relay K4 is grounded. With the signal input to displacement preamplifier V201B grounded, the servo loop is disabled and the pilot or copilot re-engages the altitude mode by copter. When the desired altitude is reached, the pilot or co-pilot re-engages the altitude mode by depressing the BAR ALT switch. Relay K7 is re-energized, the clutch in the altitude control is engaged, and the ground at the input circuit of V201B is removed, and the servo loop functions. Note that for normal operation of the altitude mode, the input to rate preamplifier V201A (coupled through ALTITUDE RATE potentiometer R511) is grounded through contacts on relay K7. This prevents the altitude servo motor from being driven by the regular periodic changes in air pressure caused by the down blasts from the main rotor blades as they rotate. If the rate signal were utilized, the main rotor blades would cause the helicopter to bounce. With the helicopter in level flight, the rotor element in the altitude control is in neutral or zero position and the output from the rotor element is zero. As long as the helicopter remains in level flight, the pressure-sensitive element in the altitude control does not actuate the clutch and the rotor element remains in the zero position. Should the helicopter change altitude in response to external forces, the pressure-sensitive element responds to the change in barometric pressure and actuates the clutch, which moves the rotor element. The change from the zero position induces a portion of the 30-volt, 400-cycle signal in the rotor. The phase and amplitude of this altitude displacement signal is such as to reflect the direction and amount of the altitude deviation.

b. Servo Amplifiers. The signal from altitude preamplifier V2B is applied through the contacts of relays K7 and K4 to the input of displacement preamplifier V201B, and to ALTITUDE RATE potentiometer R511. The output signal from V201B is applied to mixer-discriminator V203. The output signal from ALTITUDE RATE potentiometer R511 is applied through contacts on K7 to rate preamplifier V201A. The signal is amplified by V201A

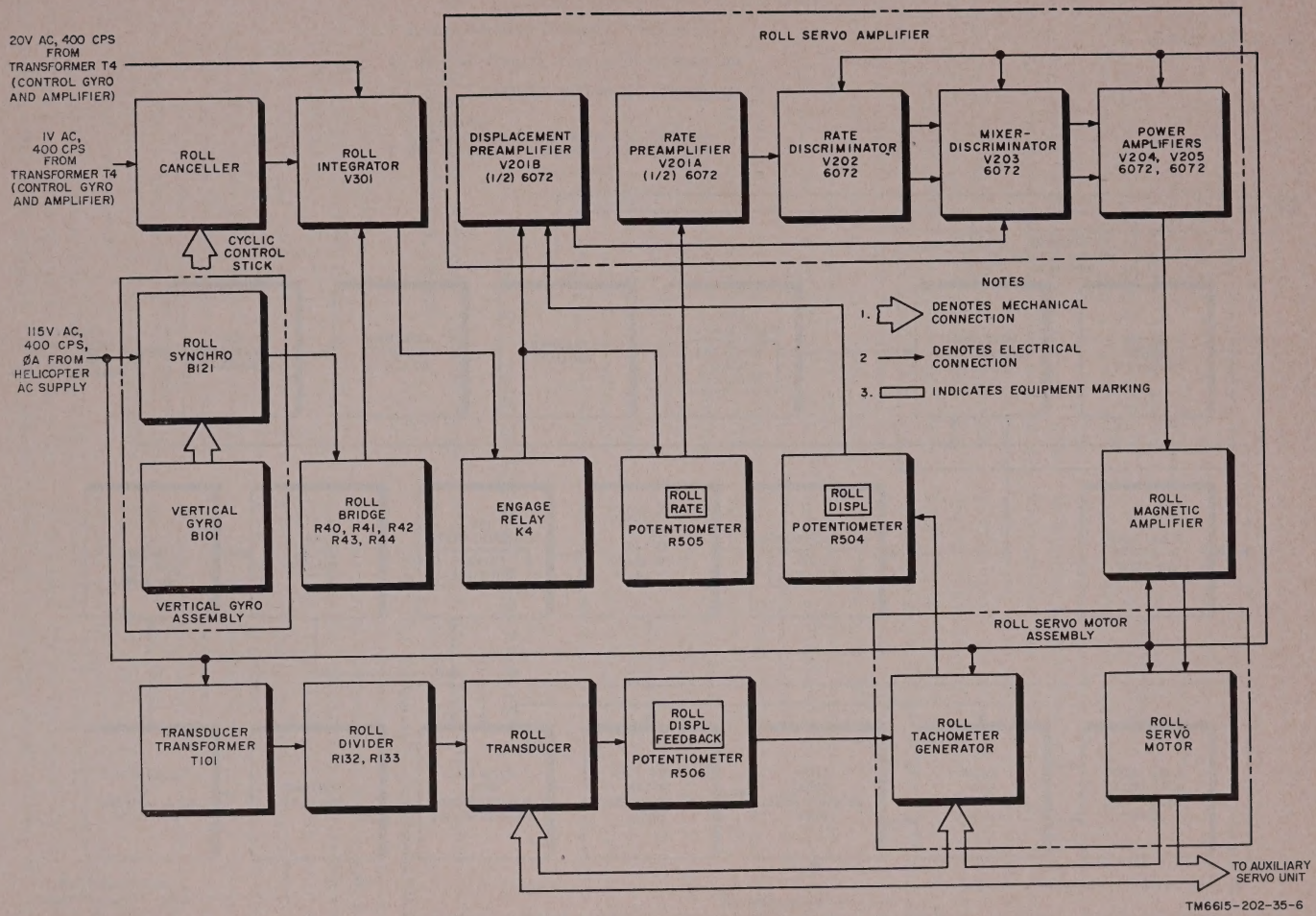
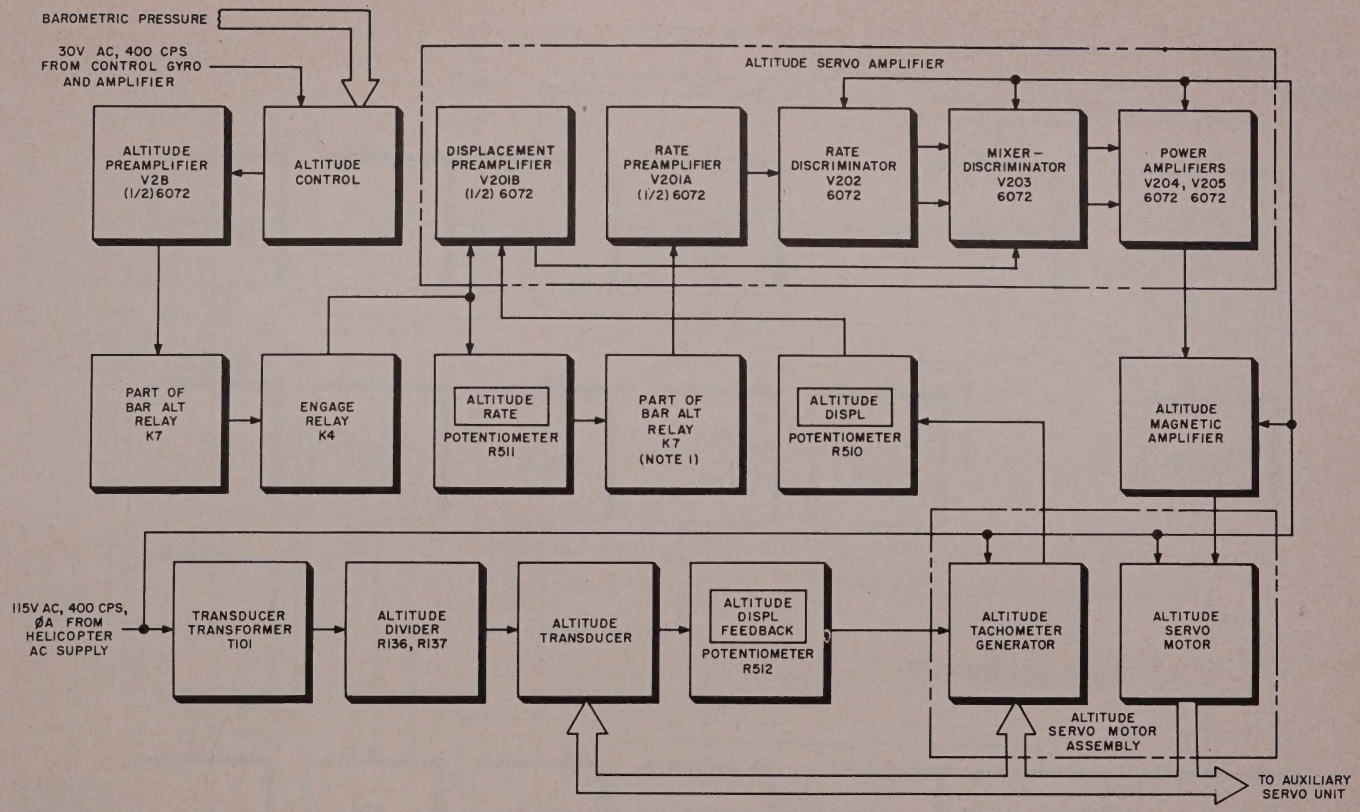


Figure 9. Roll mode, block diagram.



NOTES

1. BAR ALT RELAY K7 GROUNDS INPUT TO RATE PREAMPLIFIER V201A WHEN ALTITUDE MODE IS ENGAGED.
2. ⇨ DENOTES MECHANICAL CONNECTION
3. → DENOTES ELECTRICAL CONNECTION
4. ▭ INDICATES EQUIPMENT MARKING

TM6615-202-35-39

Figure 10. Altitude mode, block diagram.

and applied to the input of rate discriminator V202. Rate discriminator V202 has both of its input circuits paralleled and as a result both halves of V202 are driven by the output signal from V201A. The output signals from V202 together with the output signal from V201B are applied to the input of mixer-discriminator V203. The output of V203 is applied to push-pull, parallel power amplifiers V204 and V205. The output from V204 and V205 drives the altitude magnetic amplifier, which in turn provides the driving energy for the altitude servo motor. The servo motor is driven in the direction and for a length of time that corresponds to the phase and magnitude of the original change of helicopter altitude displacement signal. The altitude servo motor is mechanically coupled to the altitude tachometer generator and the altitude transducer. The feed-back signal return for altitude displacement pre-amplifier V201B is through ALTITUDE DISPL potentiometer R510, one winding of the altitude tachometer generator, and ALTITUDE DISPL FEEDBACK potentiometer R512. ALTITUDE DISPL FEEDBACK potentiometer R512 also receives the signal from the altitude transducer. The altitude tachometer generator has its other winding connected to the 115-volt, 400-cycle, phase A line and, together with the signal return current from V201B (combined with the transducer feed-back signal) produces a torque in the tachometer generator. Since the transducer, the tachometer generator, and the servo motor are mechanically coupled, the initial motor rotation produces a signal in the transducer which represents the rate of motor movement and total distance of motor rotation. The resultant net current and the displacement signal through the tachometer generator winding produce a torque in the tachometer generator opposite to the direction of servo motor rotation. This negative feed-back loop action dampens overshoot of the servo motor, thus preventing motor hunting. In addition, the transducer output provides a signal to return the servo motor to its zero position. As long as the servo motor is off the center, or zero position, the transducer will also be off its zero setting and will apply a driving signal to the servo motor. When the servo motor reaches zero position (center position), transducer output is zero; therefore, servo motor rotation stops. With the servo motor at its center position, the servo system can now respond evenly to changes in helicopter altitude deviation. The signal for the transducer is obtained from transducer transformer T101, which applies the signal to the transducer in parallel with the altitude divider. The divider provides the ground or zero reference for the transducer.

c. Phase A, 115-volt, 400-cycle Line. The phase A, 115-volt, 400-cycle line supplies operating potentials for servo amplifier tubes, the magnetic amplifier, the servo motor, the tachometer generator, the motor generator, and transducer transformer T101.

Section III. UNIT BLOCK DIAGRAM ANALYSIS

8. Block Diagram Analysis, Control Panel Assembly Model No. 2560E

(fig. 11)

The control panel contains switches, controls, and a meter indicator used by the pilot to control operation of the autopilot.

a. ENG Switch and Lamp S101. ENG switch S101 engages the pitch, roll, and yaw modes. Depressing ENG switch (and lamp) S101 energizes relays K3 and K4 in the control gyro and amplifier (fig. 66). The autopilot system emergency release relay (fig. 23) is also energized by ENG switch S101, applying ac excitation voltage to the magnetic amplifiers and servo motors.

b. BAR ALT Switch and Lamp S102. BAR ALT switch (and lamp) S102 engages the altitude mode. Depressing switch S102 energizes altitude control relay K7 in the control gyro and amplifier, and engages the altitude control clutch.

c. STANDBY Switch S105. Depressing STANDBY switch S105 disengages the pitch, altitude, roll, and yaw modes by opening the holding circuit from engage relay K3; this places the autopilot in a standby condition. Depressing STANDBY switch S105, however, does not de-energize the emergency release relay. Therefore, excitation voltage is still applied to the magnetic amplifiers and servo motors. The autopilot modes can be re-engaged from the standby condition by depressing the ENG and BAR ALT switches, in that order.

d. BAR ALT OFF Switch S106. The altitude channel can be independently disengaged, by depressing BAR ALT OFF switch S106. When S106 is depressed, the altitude signal channel opens by breaking the holding circuit to relay K7 and the

altitude control clutch is released. Disengaging the altitude channel does not affect operation of the pitch, roll, and yaw channels.

e. NULL INDIC Meter M101. NULL INDIC meter M101 is a center reading indicator used to monitor the position of each servo motor (indicative of the magnitude and direction of each servo motor input signal), for the pitch, altitude, roll, or yaw channels. During automatic flight operation, NULL INDIC meter M101 also monitors the pitch servo channel, and is used in conjunction with C G TRIM control B102 to adjust for shifts in the center of gravity of the helicopter.

f. C G TRIM Control B102. C G TRIM control B102 produces an output displacement signal which is applied through the PITCH DISPL potentiometer to the pitch servo amplifier to modify the pitch displacement signal. Adjustment of C G TRIM control B102 causes the pitch mode to compensate for forward and aft shifts in the center of gravity of the helicopter.

g. YAW TRIM Synchro B101. YAW TRIM synchro B101 is a differential synchro used to modify the yaw displacement signal received from the J2 compass system. The output of synchro B101 is fed to the yaw synchronizer assembly, causing the yaw channel to provide a heading change equal to the output of the synchro. The synchro provides slight changes in the heading of the helicopter during automatic flight, with each index mark on the front panel representing 1° of heading change.

h. AC-DC Distribution and Panel Lights. The control panel routes the 1-volt ac excitation voltage from transformer T4 to the pitch and roll cancellers. The 28-volt dc relay control voltage from time delay relay K9 passes through the control panel to the pilot's and copilot's pedal switches and AUTO STAB RELEASE switches. The return from the pedal switches is routed through the control panel to engage relay K3 while the return from the AUTO STAB RELEASE switches is applied to ENG switch S101 and STANDBY switch S105. Panel lights DS101, DS102, and DS103 are energized through the panel light dim rheostat of the lighting system of the helicopter.

9. Block Diagram Analysis, Control Gyro and Amplifier Assembly Model No. 1005N (fig. 66)

a. General. Power is applied to the control gyro and amplifier from the AC-DC interlock relay. Phase A of the 115-volt, 400-cycle power is applied directly to transformers T4, T5, and T6 in the power supply on the main chassis assembly. The output voltages of the three transformers are distributed to the various subassemblies. All three phases of the 115-volt, 400-cycle input are applied to gyro B111 in the vertical gyro assembly. The filaments of the tubes in the servo amplifier assemblies, main chassis assembly, and multiple-channel amplifier assembly receive 28 volts dc directly from the AC-DC interlock relay.

b. Pitch Displacement Signal. The pitch displacement signal generated in the vertical gyro assembly is applied through the pitch bridge resistors to displacement preamplifier V201B, and through PITCH RATE potentiometer R508 on the 12-signal adjustment assembly to rate preamplifier V201A of the pitch servo amplifier. The rate signal from discriminator V202 and the displacement signals from displacement preamplifier V201B are mixed in this servo amplifier, and the amplified displacement signal is applied to the pitch magnetic amplifier in the motor box.

c. Roll Displacement Signal. The roll displacement signal is generated in the vertical gyro assembly and applied to the roll servo amplifier through the roll integrator in the multiple-channel amplifier assembly, and the 12-signal adjustment assembly. As with the pitch signal, the rate and displacement signals are mixed, amplified, and applied to the roll magnetic amplifier in the motor box.

d. Yaw Displacement Signal. The yaw displacement signal enters the control gyro and amplifier through the yaw synchro in the yaw synchronizer assembly and is then applied to the turn amplifier in the multiple-channel amplifier assembly. The amplified output of the turn amplifier is fed back into the yaw synchronizer assembly. The signal is then applied to the 12-signal adjustment assembly, which adjusts the bias of the preamplifiers in the yaw servo amplifier and applies the signal to the preamplifier. The mixing and amplification process is the same as for the pitch and roll signals.

e. Altitude Displacement Signal. The altitude displacement signal enters the control gyro and amplifier through the altitude control preamplifier, which applies the amplified signal to the primary winding of transformer T9. The output of T9 is applied to the altitude servo amplifier through altitude control relay K7, and the 12-signal adjustment assembly. The mixing and amplification process is again the same as for the pitch and roll signals.

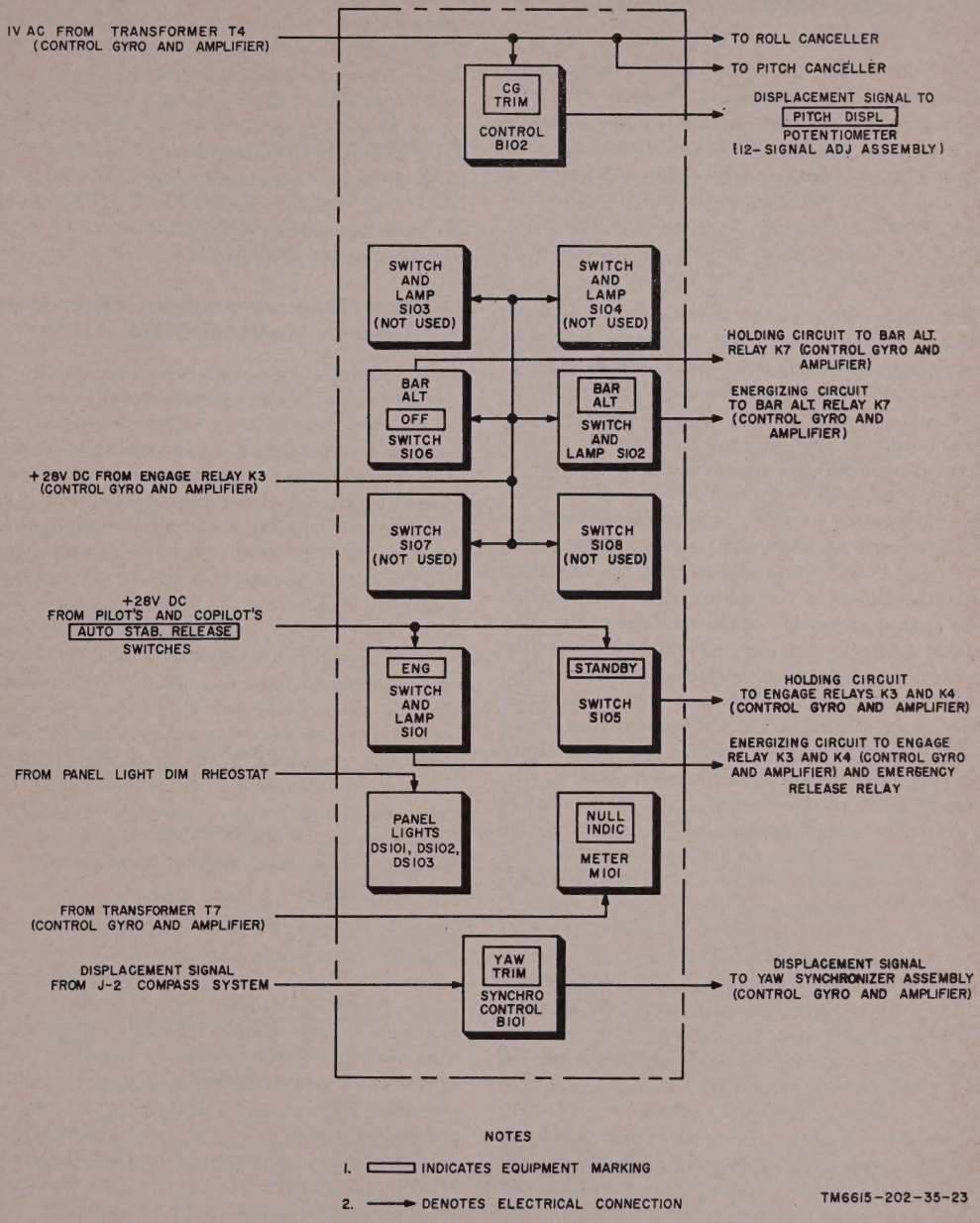


Figure 11. Control panel assembly model No. 2560E, block diagram.

10. Block Diagram Analysis, Motor Box Assembly Model No. S1645–61145

(fig. 67)

a. General. The motor box converts varying DC displacement signals from the control gyro and amplifier to ac signals which control the operation of the servo motors. The servo motors in turn operate the auxiliary and tail rotor servo units to compensate for helicopter deviations from the altitude chosen by the pilot. Provisions are also incorporated in the motor box to check the operation of various circuits and the servo motors.

b. Pitch, Altitude, Yaw, and Roll Channels. Phase A of the 115-volt, 400-cycle input is applied to a magnetic amplifier, TACH. GEN. potentiometer, and the channel disengage switch of each channel. Varying DC displacement signals in the pitch, altitude, yaw, and roll channels are applied from the control gyro and amplifier to the control winding of their respective magnetic amplifier. Each magnetic amplifier is basically a saturable reactor with an excitation, control, and output winding. Displacement signals from the respective servo amplifiers in the control gyro and amplifier are applied across the control windings of the associated magnetic amplifier. The magnetic amplifier generates an ac output voltage only if the control winding is excited. This output voltage, reflecting the characteristics of the DC displacement signal from the servo amplifier, provides operating voltage for the rotor winding of the servo motor. The TACH GEN potentiometers adjust the amount of excitation voltage applied to the stator of the tachometer generators to eliminate overshoot and damage to the servo motors. The CHANNEL DISENGAGE switches apply 115 volts AC phase A, 400 cps to the stator of the servo motors. The pilot can disengage a defective channel and still have use of the other channels by operating the CHANNEL DISENGAGE switch associated with the defective channel. Transducer transformer T101 provides excitation voltage for the pitch, altitude, yaw, and roll transducers. The primary winding is connected to the phase A, 400-cycle, 115-volt supply. The secondary windings provide an 8-volt excitation voltage across each of the four transducers. The F. U. NULL potentiometers, located in each secondary circuit of transformer T101, adjusts the null voltage output of the transducers to properly center the servo motors. OVERRIDE CHECK switch S3, across each F. U. NULL potentiometer, is used to drive the servo motors hard-over. Dividers in each transducer transformer secondary provide a zero reference for the transducers. CHANNEL SELECTOR switch S1 receives displacement or feedback signals from the magnetic amplifiers, dividers, and transducers. The switch provides a means of selecting a channel to be monitored. MOTOR POSITION-MOTOR INPUT switch S2 checks the servo motor position or servo motor input. The output of this switch is applied to the NULL INDIC meter on the control panel through transformer T7 on the control gyro and amplifier.

11. Block Diagram Analysis, Servo Motor Assembly Model No. S1665–61755

(fig. 12)

a. General. The servo motor assembly contains a servo motor, tachometer generator, transducer, and a mechanical linkage. The servo motor is mechanically coupled to the tachometer generator. AC variations from the associated magnetic amplifier in the motor box are applied to the rotor winding of the servo motor. The servo motor mechanically operates the auxiliary servo unit (pitch, roll, and altitude servo motors) or tail rotor servo unit (yaw servo motor) which operates the helicopter flight controls to maintain the attitude and/or altitude established by the pilot or copilot. The transducer, which is mechanically coupled to the rotor of the tachometer generator, electrically nulls the servo motors by producing a feed-back signal of the proper phase to dampen servo motor rotation. This feed-back signal, which is proportional to servo motor velocity, minimizes overshooting of the servo motor and hence the helicopter flight controls.

b. Servo Motor and Tachometer Generator. The phase A, 115-volt, 400-cycle input is applied to the stator windings of the servo motor and tachometer generator. The AC control signal from the appropriate magnetic amplifier output winding in the motor box is applied to the rotor of the servo motor. Any variation in the magnetic amplifier output causes servo motor rotation and hence tachometer generator rotation. The altitude, yaw, and roll tachometer generator outputs are applied to their respective servo amplifiers through their associated DISPL potentiometers in the 12-signal adjustment assembly of the control gyro and amplifier. The pitch tachometer generator output is coupled along with the C G TRIM control and pitch canceller signals, to the pitch servo amplifier through the

PITCH DISPL potentiometer in the control gyro and amplifier.

c. Transducer. The transducer is mechanically coupled to the tachometer generator rotor. The transducer is, in effect, a linear displacement potentiometer. The wiping arm contact is displaced from its null position by servo motor rotation whenever a displacement signal is initiated. A feed-back signal from the transducer is applied to the rotor of its respective tachometer generator through an associated DISPL FEEDBACK potentiometer in the control gyro and amplifier to null the servo motor. The transducer receives 8 volts ac, 400 cps from the appropriate winding of transducer transformer T101 in the motor box.

12. Block Diagram Analysis, Control Stick Canceller Assembly Model No. 911D

(fig. 13)

a. General. The pitch and roll cancellers are mechanically coupled to the pilot's and copilot's cyclic control sticks and produce signals to cancel the displacement signals of the pitch and roll channels when the pilot manually changes the attitude of the helicopter.

b. Pitch Canceller. The pitch canceller is a variable induction transformer whose stator (primary) is energized by a 1-volt, 400-cycle ac voltage. The amplitude and phase of the voltage induced into the rotor (secondary) is proportional to the angular displacement of the rotor with respect to the stator. *Fore* and *aft* movement of either the pilot's or copilot's cyclic control stick changes the pitch of the helicopter and produces a proportional output signal from the rotor. The output signal is applied through engage relay K4 and PITCH DISPL potentiometer R507 on the 12-signal adjustment assembly to displacement preamplifier V201B of the control gyro and amplifier, and cancels the pitch displacement signal generated in the channel. The

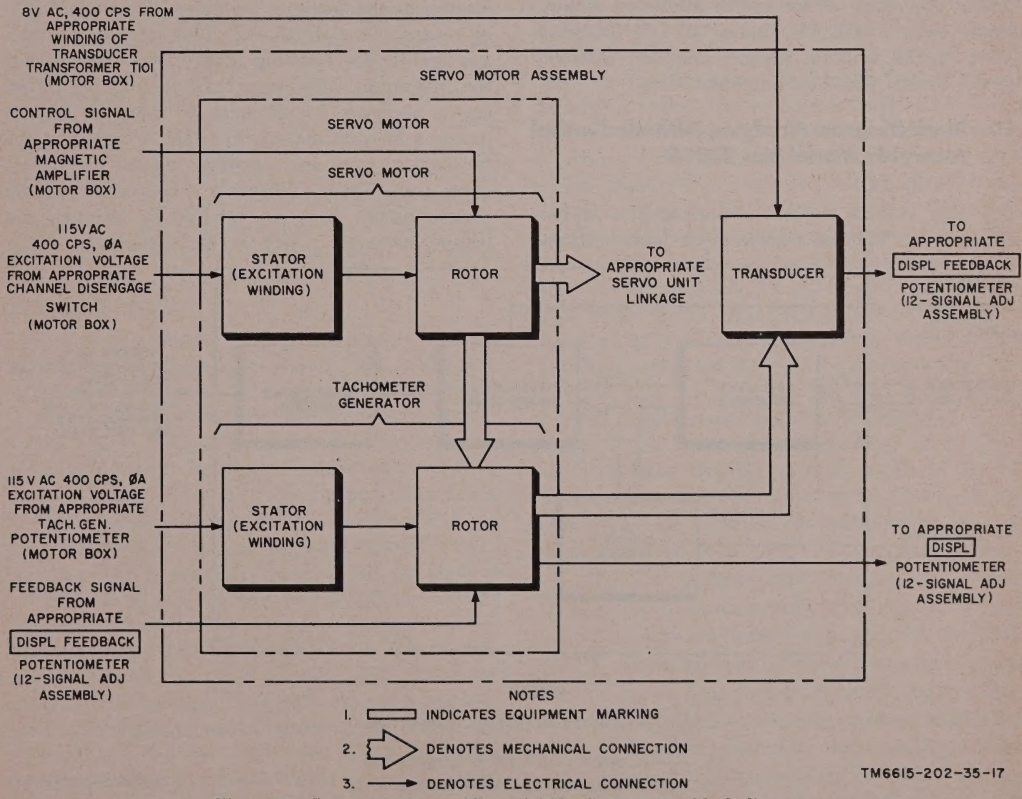


Figure 12. Servo motor assembly model No. S1665–61755, block diagram.

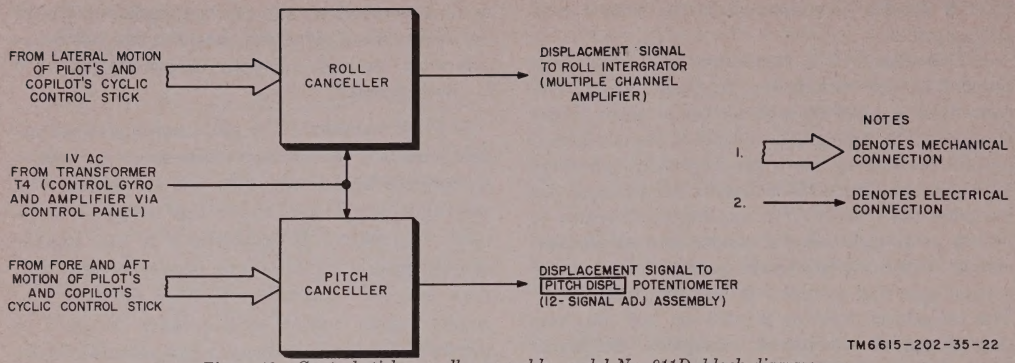


Figure 13. Control stick canceller assembly model No. 911D, block diagram.

pitch canceller signal thus prevents the pitch mode from opposing the pilot-controlled pitch alteration.

c. Roll Canceller. The operation of the roll canceller is identical with that of the pitch canceller except that the roll canceller signal, determined by *lateral* movement of either the pilot's or copilot's cyclic control stick, is applied to roll integrator V301 on the multiple channel amplifier assembly in the control gyro and amplifier.

13. Block Diagram Analysis, Altitude Control Assembly Model No. 2203G

(fig. 14)

a. The altitude control, comprised of a bellows assembly, differential transformer, clutch coil, and an adjustment control, provides an altitude displacement signal whenever barometric pressure changes occur because of deviations in helicopter altitude from an established altitude.

b. The barometric-sensitive bellows assembly is coupled mechanically to the differential transformer by means of the clutch coil. This mechanical linkage enables the coupling between windings within the differential transformer to be varied. The clutch coil is energized by 28 volts dc from the control panel; a 30-volt, 400-cycle, phase A voltage from the control gyro and amplifier excites the differential transformer. Whenever a helicopter altitude change occurs from an established altitude, the bellows assembly reacts to this change and varies

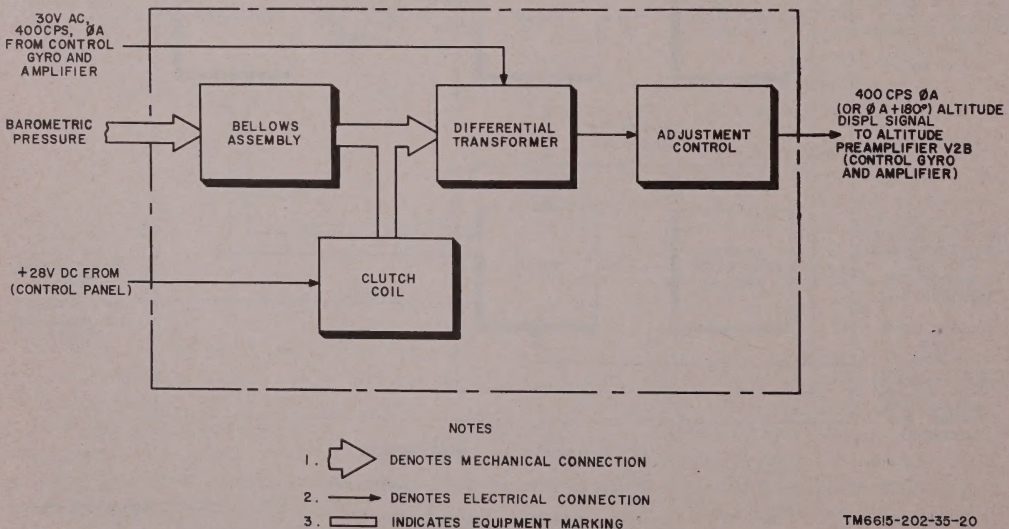


Figure 14. Altitude control assembly model No. 2203G, block diagram.

the differential transformer output. A zero reference is established with the 30-volt, 400-cycle, phase A voltage applied to the differential transformer. The varying output of the differential transformer constitutes the altitude displacement signal. This signal is a 400-cycle, phase A or phase A plus 180°, depending on the direction of altitude change. The displacement signal is applied to altitude preamplifier V2B in the control gyro and amplifier through the adjustment control. The adjustment control enables presetting the amplitude of the altitude displacement signal.

Section IV. SYSTEM SCHEMATIC ANALYSIS

14. Yaw Mode, Schematic Analysis
(fig. 68)

a. General. The yaw attitude of the helicopter is held constant by the yaw channel of the autopilot. The pilot establishes the course through normal use of the cyclic control stick and turn pedals to agree with a compass heading from the helicopter gyro magnetic compass system. A yaw displacement signal is generated in the compass system whenever the helicopter is displaced from the established heading. The displacement signal is applied through YAW TRIM synchro B101 to the synchro in the yaw synchronizer assembly. The output of the yaw synchronizer assembly is processed in the yaw servo amplifier and applied to the yaw servo motor, through the motor box, where it activates the tail rotor servo unit. The tail-rotor servo unit then actuates the flight control system to return the helicopter to its reference heading. The heading reference signal from the compass system can be modified by YAW TRIM synchro B101 to make small changes in course.

b. Circuit Operation. The yaw mode is engaged when normally open ENG switch S101 on the control panel is closed. At this time the 28-volt dc appearing at pin F of connector J4 energizes engage relay K3. Yaw transfer relay K2 is then energized from the 28-volt dc input through make contacts 4–3 of engage relay K3. Synch turn relay K5 is energized prior to engagement of the autopilot and remains energized during operation, except when a manual turn is made. The +28-volt dc input is taken from contact 4 of engage relay K3 and applied to synch turn relay K5 through contacts 5 and 4 of left turn relay K10 and contacts 5 and 4 of right turn relay K11 to pin 2 of relay K5. When the helicopter veers from the preset course, a yaw displacement signal is generated within the J2 compass system and fed to the stator of YAW TRIM synchro B101. The YAW TRIM control is a differential synchro used under certain conditions to modify the yaw mode (*c* below). With the YAW TRIM control set to zero position, the yaw displacement signal on the stator is induced into the rotor unchanged. The yaw displacement signal is applied from the rotor of the YAW TRIM control to the stator of the yaw synchro in the yaw synchronizer assembly. The rotor of the yaw synchro is mechanically coupled to the yaw motor-generator in the yaw synchronizer assembly. The yaw motor-generator does not rotate except when making manual turns. The yaw displacement signal applied to the synchro stator from the YAW TRIM control is a 400-cycle, AC voltage which is coupled to the rotor by transformer action. The phase of the signal induced into the synchro rotor is determined by the *direction* of helicopter displacement, and the voltage is determined by the *amount* of displacement. This signal appearing across pins 5 and 4 of connector J22 is applied to the input of yaw displacement preamplifier V401B in the yaw servo amplifier (fig. 76) through resistor R6, contacts 9 and 10 of yaw transfer relay K2, and Pin 9 of connector J10. The yaw displacement signal is also applied through a strap in the yaw servo amplifier to YAW RATE potentiometer R502 through pin 8 of connector J10 and pin 4 of connector J6 (fig. 68). A portion of the yaw displacement signal is then applied to the input of yaw rate preamplifier V401A in the yaw servo amplifier through pin 3 of connector J6 and pin 7 of connector J10. The yaw displacement and rate signals are combined and amplified in the yaw servo amplifier.

(1) The resultant output voltage, whose polarity is determined by the direction of helicopter displacement and whose amplitude is determined by the amount of displacement, is applied from pins 7 and 8 of connector J11 to terminals 1 and 3 of the yaw magnetic amplifier control winding in the motor box. Capacitors C101 and C102 connected across control winding terminals 3

and 2, and 2 and 1, respectively, prevent noise signals from producing a magnetic amplifier output.

(2) The magnetic amplifier is a saturable reactor with an excitation, control, and output winding, and two cores. Terminal 5 of the excitation winding is connected to terminal 3 of the ground bus while terminal 4 of the excitation winding is connected to terminal 8 of the 115-volt, 400-cycle, phase A bus. The excitation winding is connected across both cores of the magnetic amplifier. The two series-connected output windings (6–7) are oppositely wound, one on each core, so that the induced voltages in the windings oppose and cancel each other with no control voltage present in the control winding. The two series-connected control windings 1–2 and 2–3 are also oppositely wound, one on each core. The permeability of the magnetic amplifier core is controlled by a +275-volt DC input to terminal 2 of the control winding from pin J of connector J3 on the gyro control and amplifier. When a DC displacement signal from the yaw servo amplifier is applied across the control windings, the voltages across the two windings with respect to the common center are opposite in polarity. The relative polarity of the voltages in the two windings depends on the polarity of the output voltages of the servo amplifier. The difference in polarity of the voltages in the control winding tends to magnetically saturate one core of the magnetic amplifier and decrease the magnetic flux in the other core. This difference in magnetic flux between the two cores decreases the induced ac voltage in the output winding on one core and increases it on the other to produce a difference voltage across output winding 6–7. The phase, voltage, and duration of the ac output of the yaw magnetic amplifier is controlled by the polarity, voltage, and duration of the DC output of the yaw servo amplifier. Capacitor C109, connected across output winding 6–7 provides a phase correction for the magnetic amplifier output voltage. The magnetic amplifier produces a 400-cycle, ac voltage which is applied to terminal 2 of the stator winding of the yaw servo motor from terminal 6 of the magnetic amplifier. Terminal 4 of the yaw servo motor rotor winding is returned to the ground bus through pin C of connector J13 (yaw servo motor assembly) and pin C of connector J14 (motor box).

(3) CHANNEL DISENGAGE YAW switch S7 provides continuity for the excitation voltage applied to servo motor winding 1–3 from terminal 6 of the 115-volt, 400-cycle, phase A bus. Terminal 3 of the servo motor winding is grounded through pin C of connector J13 (yaw servo motor assembly) and pin C of connector J14 (motor box) to terminal 1 of the ground bus. The CHANNEL DISENGAGE YAW switch enables the pilot to disengage the yaw mode from the autopilot and still retain the use of the other modes. The primary winding of transducer transformer T101 is connected between terminal 5 of the 115-volt, 400-cycle, phase A bus and terminal 1 of the ground bus. The yaw transducer forms a bridge with resistors R130 and R131. A zero voltage reference is established between the transducer wiping arm and the junction of resistors R130 and R131.

(4) The yaw tachometer generator is mechanically coupled to the yaw servo motor and the yaw transducer. Excitation voltage for tachometer generator winding 7–10 is determined by the setting of TACH. GEN. Y potentiometer R105. Servo motor rotation causes a voltage to be induced in tachometer generator winding 8–9 and also displaces the transducer from its null (center) position. With the transducer displaced from null, a feedback voltage from the transducer output tap is developed across YAW DISPL FEEDBACK potentiometer R503, and a portion is applied to winding 8–9 of the yaw tachometer generator. The displacement feedback voltage and the output voltage from the tachometer generator are applied in series through cross-feed potentiometer R27 and YAW DISPL potentiometer R501 to the cathode of displacement preamplifier V201B (fig. 76) through pin 3 of connector J10. The amplitude of this feedback voltage is greater

than the original displacement signal and is of opposite polarity. The output signal from tachometer generator output winding 8–9 dampens servo motor rotation by placing a signal at the cathode of the displacement preamplifier which is in phase with the signal at the grid. This is the same as placing a reverse polarity signal on the grid. Servo motor rotation actuates the tail rotor servo unit, which alters the heading of the helicopter to compensate for the yaw displacement. The transducer feedback signal still exists because the wiper arm remains displaced and continues to apply a feedback signal, which is of opposite polarity to the displacement preamplifier; thereby canceling the original displacement signal. Thus, the dc output of the yaw servo amplifier also has a polarity opposite to the polarity of the signal produced by the original displacement signal. This servo amplifier output causes the servo motor to rotate in the opposite direction until the helicopter returns to its reference flight heading, at which time the tail rotor pedal controls are returned to their original position. When the helicopter returns to its reference heading, the servo motor and transducer are again at their null position.

(5) YAW DISPL FEEDBACK potentiometer R503 controls the amount of feedback from the transducer to the yaw servo amplifier. YAW DISPL potentiometer R501 controls the gain of the displacement preamplifier to provide sufficient signal strength to operate the servo motor. F. U. NULL Y potentiometer R101 adjusts the null voltage to the yaw servo motor to center the motor. TACH. GEN. Y potentiometer R105 adjusts the excitation voltage to the tachometer generator in the servo motor to prevent oscillations (overshooting). OVERRIDE CHECK switch S3, connected across F. U. NULL Y potentiometer R101, checks the total travel of the yaw servo motor. When the switch is operated, one section of the bridge is shorted; this unbalances one section of the yaw transducer and causes a voltage to be supplied to the yaw servo amplifier. The polarity of the dc output voltage from the servo amplifier is determined by the position to which the OVERRIDE CHECK switch is operated. The servo motor can then be checked for total travel in both directions.

c. Turn Circuit Operation. When the pilot or copilot uses the tail rotor pedals to change the heading of the helicopter, a normally closed pedal switch opens, de-energizing synch turn relay K5 and yaw transfer relay K2 by removing the +28 volts dc energizing voltage. A yaw displacement signal also originates in the J2 compass system because of the pilot's change of heading and is applied to the yaw synchro in the same manner as a normal yaw displacement signal (*b* above). However, the yaw displacement signal from the rotor of the yaw synchro is now applied through contacts 14–13 of yaw transfer relay K2 and developed across load resistor R51 instead of being applied to the yaw servo amplifier. Resistor R6 and capacitor C1 form a filter to reduce transient voltages due to relay contact operation. This yaw displacement signal is also applied across turn motor VEL. GEN. QUAD potentiometer R603 through contacts 7–8 of yaw transfer relay K2 and resistors R3 and R5. Resistors R2 through R5 form an isolation and impedance-matching network between the yaw synchro rotor and transformer T1 secondary. The main field of the yaw synchronizer assembly turn generator is excited by a 20-volt, ac, phase A source from the secondary of transformer T4 through pin 7 of J23 (control gyro and amplifier (CG&A)). This ac excitation is also applied through a phase-shifting network consisting of capacitor C14 and resistor R28 to teminal 1 of transformer T1 and also to terminal 6 on the turn generator field winding through pin 4 of J23. The voltage induced in the secondary of transformer T1 combines with the yaw displacement signal applied across turn motor VEL. GEN. QUAD potentiometer R603. The VEL. GEN. QUAD potentiometer sets the reference level of the turn generator field excitation. The output from the tap of the VEL. GEN. QUAD potentiometer is applied through the parallel combination of resistor R701 and the 5–7 winding of the turn generator field winding of the yaw synchronizer assembly to the grid of tube V303 in the multiple channel amplifier (fig. 74), through pin 6 of J14. Resistor R701 provides a load for the turn generator field. The amplified output from the turn amplifier is applied across the primary winding of output transformer T8 through pins 3 and 8 of J15 (CG&A). Capacitor C11 connected across the primary of transformer T8 bypasses noise transients which

might actuate the turn motor. The secondary of transformer T8 applies the turn amplifier output to field winding 1–2 of the turn motor through contacts 13 and 12 of engage relay K3 and contacts 10 and 11 of synch turn relay K5. Since both field windings of the turn motor have voltage applied to them, the turn motor rotates slightly, reflecting the amount of yaw signal excitation. Since the rotors of the turn motor, the turn generator, and the yaw synchro are mechanically coupled, the generator produces an output voltage from field winding 5–7, reflecting an increment of rotation. This output voltage is applied to the turn amplifier of the multiple channel amplifier through pin 1 of connector J23 (CG&A) and pin 6 of connector J14 (CG&A). The signal voltage is amplified in the turn amplifier and reapplied to turn motor field winding 1–2 as described above, causing the turn motor to rotate further. The rotor of the synchro follows the rotor of the motor generator and thereby reflects a new null position referenced to the J2 compass system. This continues while the heading of the helicopter is being changed. At the moment of completing a tail rotor pedal turn, the pilot releases the pedal being used, returning the pedal switch to its normally closed position. Closing of the pedal switch re-energizes synch turn relay K5 and yaw transfer relay K2. The turn motor stops rotating, and the mechanically coupled rotor of the yaw synchro is nulled to a position reflecting the new course as referenced to the J2 compass system. Any subsequent yaw displacement signal to the yaw servo amplifier is applied through contacts 9–10 of yaw transfer relay K2 to operate the yaw mode. The reference voltage applied across the secondary winding of transformer T1 is grounded through contacts 7 and 6 of yaw transfer relay K2, contacts 7 and 8 of right turn relay K11, and contacts 7 and 8 of left turn relay K10. Closed contacts 10 and 11 of synch turn relay K5 and contacts 13–12 of engage relay K3 disconnect the turn amplifier output signal from field winding 1–2 of the turn motor.

15. Pitch Mode, Schematic Analysis

(fig. 69)

a. General. The pitch attitude of the helicopter is held constant by the pitch mode of the autopilot. The pilot establishes the pitch attitude through normal use of the cyclic control stick. A pitch displacement signal is originated whenever the helicopter is displaced from the established pitch attitude. The displacement signal is generated and processed in the control gyro and amplifier and applied to the pitch servo motor through the motor box where it activates the auxiliary servo unit. The auxiliary servo unit then actuates the flight control system to return the helicopter to its reference pitch attitude.

b. Circuit Operation. The pitch channel is engaged when normally open ENG switch S101 on the control panel is closed. At this time the +28-volt DC input is applied to engage relay K4, through the pilot's and copilot's AUTO STAB. RELEASE switches, and ENG switch S101. When a pitch displacement occurs, the pitch channel receives a displacement signal from the stator of pitch synchro B113. The pitch displacement signal is a 400-cycle, three-phase, AC voltage, the *phase* of which is determined by the *direction* of displacement and the *voltage* by the *amount* of displacement of the pitch synchro rotor with respect to the stator. This three-phase signal is applied to a resistive bridge network consisting of resistors R33, R35, R36, and R37 and potentiometer R34. The bridge network converts the three-phase input from the pitch synchro stator to a single-phase signal, the amplitude of which is controlled by potentiometer R34. The displacement signal is applied to the pitch servo amplifier (fig. 75) through contacts 9 and 10 of engage relay K4 and pin 9 of connector J18. The displacement signal is also applied through a strap in the pitch servo amplifier to PITCH RATE potentiometer R508 from pin 8 of connector J18 (CG&A) and pin 4 of connector J8. A portion of the signal across potentiometer R508 is routed to pitch rate preamplifier V201A in the pitch servo amplifier (fig. 75) through pin 3 of connector J8 (CG&A) and pin 7 of connector J18 (CG&A).

(1) The output of the pitch servo amplifier, reflecting the rate as well as the amount and direction of helicopter pitch displacement, is applied to pitch magnetic amplifier control winding 1–3 in the motor box from pins 7 and 8 of connector J19 (CG&A). The polarity of this signal is determined by the direction of helicopter pitch displacement, and the amplitude of the voltage by the rate and magnitude of pitch displacement. Capacitors C105 and C106, connected across control windings 2–3 and 1–2 of the pitch magnetic amplifier prevent noise signals from producing a magnetic amplifier output.

(2) The magnetic amplifier is basically a saturable reactor with an excitation, control, and output windings, and two cores. Excitation winding 4–5 is connected across both cores of the magnetic amplifier. The two series-connected output windings (6–7) are oppositely wound, one on each core, so that the induced voltages in the windings oppose and cancel each other with no control voltage applied to control windings 1–2 and 3–4. Control windings 1–2, and 2–3 are also oppositely wound, one on each core. The permeability of the magnetic amplifier core is controlled by a +275-volt DC input to terminal 2 of the control winding from pin J of connector J3 (CG&A). When a DC displacement signal from the pitch servo amplifier is applied across the control winding, the voltages across the two dindings with respect to the common center are opposite in polarity. The relative polarity of the voltages in the two windings depends on the polarity of the output voltage of the servo amplifier. The difference in polarity of the voltages in the control winding tends to magnetically saturate one core of the magnetic amplifier and decrease the magnetic flux in the other core. This difference in magnetic flux between the two cores decreases the induced ac voltage in the output winding on one core and increases it on the other to produce a difference voltage across the output winding. The phase, voltage, and duration of the AC output of the magnetic amplifier is controlled by the polarity, voltage, and duration of the DC output of the pitch servo amplifier (fig. 75). Capacitor C111, connected across output winding 6–7 provides a phase correction for the magnetic amplifier output voltage. The magnetic amplifier produces a 400-cycle voltage which is applied to stator windings 2–5 and 4–6 of the pitch servo motor. Terminal 4 of the stator winding is returned to the ground bus through pin C of connector J16 (motor box).

(3) CHANNEL DISENGAGE PITCH switch S4 provides continuity for the excitation voltage to the 1–3 winding of the pitch servo motor. Switch S4 enables the pilot to disengage the pitch mode from the autopilot and still retain the use of the other modes. The pitch transducer forms a bridge with resistors R134 and R135. A zero voltage reference is established between the transducer wiping arm and the junction of resistors R134 and R135.

(4) The pitch tachometer generator is mechanically coupled to the pitch servo motor and the pitch transducer. Excitation voltage for tachometer generator winding 7–10 is determined by the setting of TACH. GEN. P potentiometer R107. Servo motor rotation causes a voltage to be induced in tachometer generator winding 8–9 and also displaces the transducer from its null (center) position. With the transducer displaced from null, the pitch displacement signal feedback voltage which appears at the transducer output tap, is developed across PITCH DISPL FEEDBACK potentiometer R509. An amount of this voltage, determined by the setting of the wiper arm of R509, is applied in series with the voltage induced in winding 8–9 of the tachometer generator. The combined voltage output from winding 8–9 is applied in series with the C G TRIM and pitch canceller output voltages through closed contacts 3–4 of engage relay K4 and through PITCH DISPL potentiometer R507 to the cathode of displacement preamplifier V201B in the pitch servo amplifier assembly (fig. 75). Resistors R106 and R104 are part of the resistive loads across the C G TRIM control and pitch canceller. The output signal from the pitch tachometer generator dampens servo motor rotation by placing a signal at the cathode of the displacement preamplifier which is in phase with the signal at the grid. This is the same as placing a reverse polarity signal on the grid. Servo motor rotation actuates the auxiliary servo motor to return the helicopter to its reference pitch attitude, compensating for the pitch change. The transducer feed-back signal still exists because the wiping arm is displaced, and continues to feed a signal to the displacement preamplifier cathode, thereby cancelling the displacement signal. Thus, the DC output of the pitch servo amplifier also has a polarity opposite to the polarity of the sig-

nal produced by the original displacement signal. This servo amplifier output causes the servo motor to rotate in the opposite direction until the helicopter returns to its reference flight pitch attitude. When the helicopter returns to its reference flight pitch attitude, the servo motor and transducer are again at their null positions.

(5) PITCH DISPL FEEDBACK potentiometer R509 controls the amount of feedback from the transducer to the servo amplifier. PITCH DISPL potentiometer R507 controls the gain of displacement preamplifier V201B to provide sufficient signal strength to operate the servo motor. F. U. NULL P potentiometer R103 is also across the bridge network comprised of resistors R134 and R135 and the transducer. The tap of potentiometer R103 is grounded through pin 18 of connector J18 (motor box) and pin N of connector J2 (CG&A). F. U. NULL P potentiometer R103 adjusts the null voltage to the pitch servo motor to center the motor. TACH. GEN. P potentiometer R107 adjusts the excitation voltage to the tachometer generator in the pitch servo motor assembly to prevent oscillations (overshooting). OVERRIDE CHECK switch S3, connected across F. U. NULL P potentiometer, checks the total travel of the pitch servo motor. When the switch is operated, one section of the bridge is shorted; this unbalances one section of the transducer and causes a voltage to be supplied to the pitch servo amplifier. The polarity of the dc output of the servo amplifier is determined by the position to which the OVERRIDE CHECK switch is operated. The servo motor can thus be checked for total travel in both directions.

(6) When the pilot or copilot uses te cyclic control stick to initiate a change of pitch attitude, the pitch canceller actuates. The pitch canceller is a stator-excited variable transformer with the output voltage from the rotor reflecting the direction and amount of angular displacement of the rotor with respect to the stator. The *direction* of rotor travel determines the phase, and the *amount* of displacement determines the amplitude of the output voltage. Both cyclic control sticks are directly coupled to the pitch canceller rotor; therefore, movement of either cyclic control stick produces a rotor voltage directly proportional to the direction and travel of the cyclic control stick. The pitch canceller rotor output is developed across series-connected resistors R103 and R104, and a portion of the pitch canceller signal is applied to the cathode of displacement preamplifier V201B in the pitch servo amplifier (fig. 75) through pin E of connector J5 (control panel), pin E of connector J4 (CG&A), contacts 3 and 4 of engage relay K4, pin 2 of connector J8 (CG&A), PITCH DISPL potentiometer R507, pin 1 of connector J8 (CG&A), and pin 3 of connector J18 (CG&A). The phase and amplitude of the canceller signal is such as to cancel the normal displacement signal applied to the grid of displacement preamplifier V201B from pitch synchro B113; therefore, the pitch servo amplifier has no output and the pitch mode does not operate.

(7) C G TRIM control B102 is a stator-excited variable induction transformer with the output voltage from the rotor reflecting the direction and amount of angular displacement of the rotor with respect to the stator. The *direction* of rotor travel determines the phase and the *amount* of displacement determines the amplitude of the output voltage. The rotor of the C G TRIM control is turned directly by manual rotation of the C G TRIM control knob. The rotor output voltage, approximately 1/10 volt per degree of rotor displacement, is developed across resistors R105 and R106, with capacitor C103 providing phase correction. Resistors R104 and R103 together with capacitor C102 form a load and phase-shifting network for the pitch canceller output. Normally, a pitch-cancelling signal is not present and a portion of the C G TRIM control output is applied to the cathode of the displacement preamplifier V201B in the pitch servo amplifier assembly (fig. 75) through pin E of connector J5 (control panel), pin E of connector J4 (CG&A), contacts 3–4 of engage relay K4, pin 2 of connector J8 (CG&A), PITCH

DISPL potentiometer R507, pin 1 of connector J8 (CG&A), and pin 3 of connector J18 (CG&A). The C G TRIM signal is either in phase or 180° out of phase with the pitch displacement signal, depending on the direction of rotation, with an amplitude proportional to the angular displacement of the rotor with respect to the stator. The C G TRIM signal applied to the cathode of pitch displacement preamplifier V201B modifies the normal pitch displacement signal applied to the grid, effectively shifting the reference center of the pitch mode to compensate for shifts in the center of gravity of the helicopter. Clockwise rotation of the C G TRIM control (toward the AFT position) causes the pitch mode to compensate for a forward shift in the center of gravity, and counterclockwise rotation (toward the FWD position) provides a pitch compensation for a tail heavy condition.

16. Roll Mode, Schematic Analysis

(fig. 70)

a. General. The roll attitude of the helicopter is held constant by the roll mode of the autopilot. The pilot establishes the roll attitude through normal use of the cyclic control stick. A roll displacement signal is originated whenever the helicopter is displaced from the established roll attitude. The roll displacement signal is generated and processed in the control gyro and amplifier and applied to the roll servo motor via the motor box where it activates the auxilary servo unit. The auxiliary servo unit then actuates the flight control system to return the helicopter to its reference flight roll attitude.

b. Circuit Operation. The roll channel is engaged when normally open ENG push-button switch S101 on the control panel is closed. At this time, the +28-volt dc input is applied to engage relay K4 through the pilot's and copilot's AUTO STAB. RELEASE switches and ENG pushbutton switch S101. When a roll displacement occurs, the roll channel receives a displacement signal from the stator of roll synchro B121. The roll displacement signal is a 400-cycle, 3-phase AC voltage, the phase of which is determined by the direction of displacement, and the voltage by the amount of displacement of the roll synchro rotor with respect to the stator. This three-phase signal is applied to a resistive bridge network consisting of resistors R40, R42, R43, and R44, and potentiometer R41. The bridge converts the three-phase input from the roll synchro stator to a single-phase signal, the amplitude of which is controlled by potentiometer R41. This displacement signal is applied to the roll integrator circuit of the multiple channel amplifier assembly (fig. 74) through pin 7 of J14. To prevent the roll channel from adding to the ground resonance effect, the roll integrator circuit introduces a time delay only when a roll canceller signal is present. For detailed circuit analysis of the roll integrator, see paragraph 19*e*. The roll displacement signal is applied from pin 9 of connector J14 of the roll integrator to roll displacement preamplifier V201B in the roll servo amplifier assembly (fig. 75), through contacts 6–7 of engage relay K4 and pin 9 of connector J16 (CG&A). This displacement signal is also applied (through a strap in the roll servo amplifier) to one end of ROLL RATE potentiometer R505 through pin 8 of connector J16 (CG&A) and pin 4 of connector J7. The signal developed across ROLL RATE potentiometer R505 is applied to roll rate preamplifier V201A in the roll servo amplifier (fig. 75) through pin 3 of connector J7 and pin 7 of connector J16 (CG&A).

(1) The output of the roll servo amplifier (fig. 75), (reflecting the rate, amount, and direction of helicopter roll displacement) is applied to roll magnetic amplifier control windings 1–2 and 2–3 in the motor box from pins 7 and 8 of connector J17 (CG&A). The polarity of this signal is determined by the direction of helicopter roll displacement and the amplitude of the voltage by the rate and magnitude of roll displacement. Capacitors C103 and C104, connected across control windings 1–2 and 2–3, prevent noise signals from producing a magnetic amplifier output.

(2) The magnetic amplifier is basically a saturable reactor with excitation, control, output windings, and two cores. Excitation winding 4–5 is connected across both cores of the magnetic amplifier. The series-connected output windings (6 and 7) are oppositely wound, one on each core, so that the induced voltages in the windings oppose and cancel each other with no control voltage applied to the control winding. Control windings 1–2 and 2–3 are also oppo-

sitely wound, one on each core. The permeability of the magnetic amplifier core is controlled by a +275-volt DC input to terminal 2 of the control winding. When a DC displacement signal from the roll servo amplifier is applied across the control winding, the voltages across the two windings, with respect to the common center, are opposite in polarity. The relative polarity of the output voltages in the two windings depends upon the polarity of the output voltage of the servo amplifier. The difference in polarity of the voltages in the control winding tends to magnetically saturate one core of the magnetic amplifier and decrease the magnetic flux in the other core. This difference in magnetic flux between the two cores decreases the induced ac voltage in the output winding on one core and increases it on the other to produce a difference voltage across the output winding. The phase, voltage, and duration of the AC output of the magnetic amplifier are controlled by the polarity, voltage, and duration of the DC output of the roll servo amplifier. Capacitor C110, connected across output winding 6–7 provides a phase correction for the magnetic amplifier output voltage. The magnetic amplifier produces a 400-cycle AC voltage which is applied to stator windings 2–5 and 4–6 of the roll servo motor.

(3) CHANNEL DISENGAGE ROLL switch S6 provides a 115-volt 400-cycle per second (cps) excitation voltage for servo motor winding 1–3. The CHANNEL DISENGAGE ROLL switch enables the pilot to disengage the roll mode from the autopilot and still retain the use of the other modes. The primary of transducer transformer T101 is connected between terminal 5 of the 115-volt, 400-cycle, phase A bus and terminal 1 of the ground bus. The roll transducer forms a bridge with resistors R132 and R133. A zero voltage reference is established between the transducer wiper arm and the junction of resistors R132 and R133.

(4) The roll tachometer generator is mechanically coupled to the roll servo motor and the roll transducer. Excitation voltage for tachometer generator winding 7–10 is determined by the setting of TACH. GEN. R potentiometer R106. A voltage is tapped off the potentiometer and applied to terminal 7 of the tachometer generator excitation winding. Terminal 10 of the excitation winding is grounded through pin C of connector J15 (motor box) and terminal 2 of the ground bus. Servo motor rotation causes a voltage to be induced in tachometer generator winding 8–9 and also displaces the transducer from its null (center) position. With the transducer displaced from null, the roll displacement signal feedback voltage which appears at the transducer output tap, is developed across ROLL DISPL FEEDBACK potentiometer R506. An amount of this voltage, determined by the setting of the wiper arm of R506, is applied in series with the voltage induced in winding 8–9 of the tachometer generator. The combined voltage output from winding 8–9 is applied in series through ROLL DISPL potentiometer R504 to the cathode of displacement preamplifier V201B in the roll servo amplifier assembly (fig. 75). The output signal from the tachometer generator dampens servo motor rotation by placing a signal at the cathode of the displacement preamplifier which is in phase with the signal at the grid. This is the same as placing a reverse polarity signal on the grid. Servo motor rotation actuate the auxiliary servo motor to return the helicopter to its reference roll attitude, compensating for the roll change. The transducer feed-back signal still exists because the wiping arm is displaced, and continues to feed a signal to the displacement preamplifier cathode, thereby cancelling the displacement signal. Thus, the DC output of the roll servo amplifier also has a polarity opposite to the polarity of the signal produced by the original displacement signal. This servo amplifier output causes the servo motor to rotate in the opposite direction until the helicopter returns to its reference flight roll attitude, and the servo motor and transducer are again at their null position.

(5) ROLL DISPL FEEDBACK potentiometer R506 controls the amount of feedback

from the transducer to the servo amplifier. ROLL DISPL potentiometer R504 controls the gain of the displacement preamplifier to provide a voltage of sufficient amplitude to operate the servo motors. F. U. NULL R potentiometer R102 is also across the bridge network comprised of resistors R132 and R133 and the transducer. The tap of potentiometer R102 is grounded through pin 18 of connector J18 (motor box) and pin N of connector J2 (CG&A). The F. U. NULL R potentiometer adjusts the null voltage to the servo motor to center the motor. The TACH. GEN. R potentiometer adjusts the excitation voltage to the tachometer generator to prevent oscillations (overshooting). OVERRIDE CHECK switch S3, connected across the F. U. NULL R potentiometer, checks the total travel of the roll servo motor. When the switch is operated, one section of the bridge is shorted, thereby unbalancing one section of the transducer and causing a voltage to be supplied to the roll servo amplifier. The polarity of the dc output of the servo amplifier is determined by the position to which the OVERRIDE CHECK switch is operated. The servo motor can thus be checked for total travel in both directions.

(6) When a manual change of roll attitude is initiated by either the pilot's or copilot's cyclic control stick, the roll canceller is actuated. The roll canceller is a stator-excited variable transformer with the output voltage from the rotor reflecting the direction and amount of angular displacement of the rotor with respect to the stator. The direction of rotor travel determines the phase, and the amount of displacement determines the amplitude, of the output voltage. Both the pilot's and copilot's cyclic control stick is directly coupled to the roll canceller rotor. Therefore, movement of either cyclic control stick produces a rotor voltage directly proportional to the direction and travel of the cyclic control stick. The roll canceller rotor output signal is applied to the roll integrator circuit of the multiple channel amplifier (fig. 74) through pins 2 and 8 of connector J14 (CG&A). Capacitor C101 provides phase correction for the roll canceller output. The roll canceller signal is delayed in the roll integrator to prevent the roll mode from adding to the ground resonance effect, and is combined at the output with the roll displacement signal. The amplitude of the canceller signal is equal, but opposite in phase, to the roll displacement signal. Therefore, the roll channel receives no effective input and the roll mode does not operate.

17. Altitude Mode, Schematic Analysis

(fig. 71)

a. General. The altitude of the helicopter is held constant by the altitude mode of the autopilot. The pilot establishes the altitude of the helicopter through normal use of the collective pitch stick. An altitude displacement signal is originated whenever the altitude of the helicopter is displaced from the established altitude. The displacement signal is processed in the control gyro and amplifier, and is applied to the altitude servo motor via the motor box where it activates the auxiliary servo unit. The auxiliary servo unit then actuates the flight control system to return the helicopter to its reference flight altitude.

b. Circuit Operation. The altitude channel is engaged when normally open BAR ALT pushbutton switch S102 on the control panel is depressed. Prior to engaging the altitude channel, however, the other modes must be in operation. The pitch, roll, and yaw modes are engaged when normally open ENG switch S101 on the control panel is depressed. At this time, the 28-volt DC input is applied to engage relays K3 and K4 through the pilot's and copilot's AUTO STAB. RELEASE switches and ENG switch S101. With engage relay K3 energized, the 28-volt DC input is applied to BAR ALT switch S102 through pin V of connector J2 (CG&A) and contacts 9–10 of engage relay K3. Depressing BAR ALT switch S102 applies 28 volts dc to relay K7 and to the altitude control through pin D of connector J3 (CG&A) and pin E of connector J9 (altitude control). The BAR ALT indicating lamp lights when the BAR ALT switch is depressed. With relay K7 energized, contacts 12–13 close to provide a holding circuit for relay K7 through pins R and S of connector J1 (CG&A). Depressing BAR ALT OFF switch S106 de-energizes relay K7, thereby disengaging the altitude channel.

(1) The altitude control provides the altitude displacement signal. The output signal is a variable 400-cycle voltage. The phase of this signal, phase A or phase A plus 180°, is determined by the direction of displacement; the voltage is determined by the amount of displacement. With the altitude mode engaged, the altitude control clutch coil is energized by the +28-volt dc input through pin D of connector J3 (CG&A) and pin E of connector J9 (altitude control). The return path for the clutch coil is through pin D of connector J9 (altitude control) and pin N of connector J3 (CG&A) to ground. With the clutch coil energized, the clutch mechanism is engaged. The clutch mechanism, coupled with the mechanical linkage, forms a bellows assembly which is connected to a rotating metal bar. The rotating bar differentially varies the inductive coupling between primary windings P1 and P2, and secondary winding S of a variable inductance transformer. The two primary windings are connected in series but are oppositely wound. They are excited by phase A of the 400-cycle, 30-volt input through pin C of connector J9 (altitude control) and M of J3 (CG&A). The ground return for both windings is through pin D of J9 altitude control) and N of connector J3 (CG&A). The coupling bar is spring-held in its neutral position when the clutch is not engaged. In this neutral position, the inductive coupling between windings P1 and S is equal to that between windings P2 and S, and no voltage is induced in winding S. When the clutch is engaged, changes in barometric pressure, reflecting changes in helicopter altitude, rotate the variable inductive coupling bar from its neutral position so that a signal is induced in winding S. This signal is fed into the altitude channel through a 5,000-ohm sensitivity adjustment potentiometer, and pin A of connector J9 (altitude control). When an altitude displacement occurs, the altitude channel receives a displacement signal from the altitude control. The altitude control output is applied to the grid of altitude preamplifier V2B through pin A of connector J9 (altitude control) and pin K of connector J3 (CG&A).

(2) Resistors R23, R24, and R25 are the cathode, grid, and plate load resistors, respectively. BAR. ALT. PRE-AMP potentiometer R605 adjusts the sensitivity of altitude preamplifier V2B. Capacitor C12 prevents the DC supply from saturating the primary of transformer T9, and capacitor C13 prevents transients from affecting the altitude mode. The output of altitude preamplifier V2B is applied across transformer T9 to the altitude servo amplifier (fig. 75) through contacts 6–7 of relay K7, contacts 12–13 of engage relay K4, and pin 9 of connector J12 (CG&A).

(3) The output voltage of the altitude servo amplifier is applied from pins 7 and 8 of connector J13 (CG&A) to the 1–3 control winding of the altitude magnetic amplifier in the motor box. Capacitors C107 and C108, connected across control windings 1–2 and 2–3, prevent noise signals from exciting the magnetic amplifier output.

(4) The magnetic amplifier is a saturable reactor with an excitation, a control, and an output winding, and two cores. The excitation winding is connected across both cores of the magnetic amplifier. The two series-connected output windings (6 and 7) are oppositely wound, one on each core, so that the induced voltages in the windings oppose and cancel each other with no control voltage present in the control winding. Series-connected control windings 1–2 and 2–3 are also oppositely wound, one on each core. The permeability of the magnetic amplifier core is controlled by a +275-volt dc input to terminal 2 of the control winding from pin J of connector J3 (CG&A). When a DC displacement signal from the altitude servo amplifier is applied across the control windings, the voltages across the two windings with respect to the common center are opposite in polarity. The relative polarity of the voltages in the two windings depends upon the polarity of the output voltages of the servo amplifier. The difference in polarity of the voltages in the control winding tends to magnetically saturate one core of the magnetic amplifier and

decrease the magnetic flux in the other core. This difference in magnetic flux between the two cores decreases the induced ac voltage in the output winding on one core and increases it on the other to produce a difference voltage across the output winding. The phase, voltage, and duration of the AC output of the altitude magnetic amplifier are controlled by the polarity, voltage, and duration of the dc output of the altitude servo amplifier. Capacitor C112, connected across output winding 6–7, provides a phase correction for the magnetic amplifier output voltage. The magnetic amplifier produces a 400-cycle AC voltage which is applied across the 2–5 and 4–6 rotor windings of the altitude servo motor.

(5) CHANNEL DISENGAGE ALT. switch S5 provides continuity for the 115-volt ac excitation voltage for servo motor winding 1–3. CHANNEL DISENGAGE ALT. switch S5 enables the pilot to disengage the altitude mode from the autopilot and still retain the use of the other modes. The altitude transducer forms a bridge with resistors R136 and R137. A zero voltage reference is established between the transducer wiping arm and the junction of resistors R136 and R137.

(6) The altitude tachometer generator is mechanically coupled to the altitude servo motor and the altitude transducer. Excitation voltage for tachometer generator winding 8–10 is determined by the setting of TACH. GEN. A potentiometer R108. Servo motor rotation causes a voltage to be induced in tachometer generator winding 8–9 and also displaces the transducer from its null (center) position. With the transducer displaced from null, the altitude displacement signal feedback voltage which appears at the transducer output top, is developed across ALTITUDE DISPL FEEDBACK potentiometer R512. An amount of this voltage, determined by the setting of the wiper arm of R512, is applied in series with the voltage induced in winding 8–9 of the tachometer generator. The combined voltage output from winding 8–9 is applied in series through ALTITUDE DISPL potentiometer R510 to the cathode of displacement preamplifier V201B in the altitude servo amplifier assembly (fig. 75). With the transducer displaced from null, a voltage appears on the transducer output tap. The series tachometer generator and transducer voltages are applied to the altitude servo amplifier through pin 3 of connector J12 (CG&A). The output signal from the tachometer generator dampens servo motor rotation by placing a signal at the cathode of the displacement preamplifier (in the altitude servo amplifier) of the same polarity as the signal at the grid. This is the same as placing a signal on the grid of opposite polarity to the displacement signal. Servo motor rotation alters the pitch of the rotor blades through the auxiliary servo unit, compensating for the altitude change. The transducer feed-back signal still exists because the wiping arm is displaced, and continues to feed a signal to the displacement preamplifier cathode, thereby cancelling the displacement signal. Thus, the DC output of the altitude servo amplifier also has a polarity opposite to the polarity of the signal produced by the original displacement signal. This servo amplifier output causes the servo motor to rotate in the opposite direction until the helicopter returns to its reference flight altitude, at which time the pitch of the rotor blades is returned to their original position. When the helicopter returns to its reference flight altitude, the servo motor and transducer are again at their null positions.

(7) ALTITUDE DISPL FEEDBACK potentiometer R512 controls the amount of feedback from the transducer to the altitude servo amplifier. ALTITUDE DSIPL potentiometer R510 controls the gain of the displacement preamplifier in the altitude servo amplifier to provide a voltage of sufficient amplitude to operate the servo motors. F.U. NULL A potentiometer R104 adjusts the null voltage to the servo motor to center the motor. The TACH. GEN. A potentiometer adjusts the amount of excitation voltage to the tachometer generator to prevent oscillations (overshooting).

OVERRIDE CHECK switch S3, connected across the F.U. NULL A potentiometer, checks the total travel of the servo motor. When the switch is operated, one section of the bridge is shorted, thereby unbalancing one section of the transducer and causing a voltage to be supplied to the altitude servo amplifier. The polarity of the DC output of the altitude servo amplifier is determined by the position to which the OVERRIDE CHECK switch is operated. The servo motor can then be checked for total travel in both directions. ALTITUDE RATE potentiometer R511 is not used because the static port of the helicopter is always receiving pressure variations due to rotor blast. These pressure variations may cause the helicopter to fly erratically when BAR. ALT. switch S102 is depressed. If these variations were sensed by the altitude control and fed to the rate circuit, the altitude of the helicopter would constantly vary. During normal operation, the grid of altitude rate amplifier V201A in the servo amplifier (fig. 75) is grounded through pin 7 of connector J12 (CG&A) and contacts 3–4 of relay K7.

Section V. UNIT SCHEMATIC ANALYSIS

18. Control Panel Assembly Model No. 2560E, Schematic Diagram Analysis

a. General (fig. 72). The control panel of the autopilot contains switches to engage and disengage automatic modes of operation controlling the pitch, altitude, roll, and yaw attitudes of the helicopter. It also has variable controls for compensating for shifts in the center of gravity of the helicopter and, within a relatively narrow range, adjusting the direction and amount of automatic yaw control. A meter indicator monitors servo motor position and input signals for all modes, and monitors the helicopter center of gravity during automatic flight.

b. ENG Switch S101 (fig. 72). After the equipment is warmed up and the vertical gyro is up to running speed, 28 volts dc appears at pin F of connector J5 and is routed through pin J of connector J6 to the pilot's and copilot's AUTO STAB. RELEASE switches and returned to the open terminal of the ENG switch and lamp S101 through pin K of connector J6. Depressing ENG switch S101 applies 28 volts dc to engage relays K3 and K4 in the control gyro and amplifier through pin a of connector J5 and also energizes the emergency release relay (fig. 23). Although ENG switch S101 is a momentary-action switch, the lamp associated with ENG switch S101 remains lighted from the +28 volts dc furnished through normally closed STANDBY switch S105, pin R of connector J5, and contacts 6–7 of engage relay K3 (fig. 73).

c. BAR ALT Switch S102 (fig. 72). When the pitch, roll, and yaw modes have been engaged, +28 volts dc is present on the open terminal of BAR ALT switch and lamp S102 from engage relay K3 through pin S of connector J5. Depressing BAR ALT switch S102 applies this voltage to altitude control relay K7 and to the altitude control clutch coil through pin T of connector J5, activating the altitude mode of operation. The altitude mode cannot be engaged alone since +28 volts DC is not present on BAR ALT switch S102 from pin S of J5 until the system has been engaged.

d. STANDBY Switch S105 (fig. 72). STANDBY switch S105, when depressed, removes all automatic modes of control (including the altitude mode, if it is engaged), placing the autopilot in a standby condition. Depressing STANDBY switch S105 de-energizes engage relays K3 and K4 by opening the 28-volt dc holding circuit to engage relay K3 through pin R of connector J5. Yaw transfer relay K2, altitude control relay K7, and the altitude control clutch coil are also de-energized, since energizing voltage is obtained through make contacts of engage relay K3, thus opening the yaw and altitude control channels. Depressing STANDBY switch S105 does not de-energize the emergency release relay or the time delay relay; therefore, the magnetic amplifiers in the motor box and the servo motors remain energized. The autopilot can therefore be immediately re-engaged by depressing ENG switch S101 and BAR ALT. switch S102 in that order.

e. BAR ALT. OFF Switch S106 (fig. 72). BAR ALT. OFF switch S106 opens the altitude control channel by breaking the holding circuit to altitude control relay K7 through pin U of connector J5,

thereby de-energizing relay K7 and also releasing the altitude control clutch. The altitude mode of operation may be disengaged and re-engaged at any time without affecting the pitch, roll, and yaw modes of operation.

f. NULL INDIC Meter M101 (fig. 72). NULL INDIC meter M101 is a center reading indicator used to monitor the position of the servo motors or the strength and direction of servo motor input for the pitch, altitude, roll, or yaw channels. One channel at a time can be monitored. CHANNEL SELECTOR switch S1, located in the motor box (fig. 77), selects the servo motor to be monitored, and MOTOR POSITION-MOTOR INPUT switch S2, also in the motor box, selects the type of signal applied to NULL INDIC meter M101 through pins N and P of connector J5. During automatic flight, NULL INDIC meter M101 continuously monitors the helicopter center of gravity. The signal being monitored is received from the pitch servo motor through CHANNEL SELECTOR switch S1, which is normally set to the PITCH position. NULL INDIC meter M101 is also used in conjunction with C G TRIM control B102 to check and adjust for shifts in the center of gravity of the helicopter.

g. C G TRIM Control B102 (figs. 15 and 72). C G TRIM control B102 (fig. 72) is a variable induction transformer which modifies the pitch displacement signal during autopilot engagement to compensate for shifts in the helicopter center of gravity. A variable induction transformer of this type has a closed toroidal stator (primary winding) which is excited by a low AC voltage (E_{in}) at two points physically 180° apart (fig. 15). The output voltage (E_o) from the rotor (secondary) reflects in amplitude and phase the angular position of the rotor with respect to the stator. Minimum coupling between rotor and stator produces a minimum or zero output, and maximum coupling induces a maximum output voltage from the rotor. From the top center position of the C G TRIM knob (minimum coupling) to 90° clockwise rotation of the control knob (maximum coupling) the output voltage increases, and decreases to a second null at the 180° position; the output voltage rises again to a maximum as the rotor is turned through 270°, and decreases to zero or minimum at 1 full turn. During the first half turn, the output voltage is in phase with the excitation voltage. From the 180° null position, the output voltage rises again to a maximum as the rotor is turned through 270°, and decreases to zero or minimum after one full turn. During the second half turn, the output voltage is shifted 180 electrical degrees from the excitation voltage. C G TRIM control B102 stator winding is excited with 1-volt, 400-cycle ac voltage received through pins A and D of connector J5 (fig. 72). Clockwise rotation of C G TRIM control B102 (toward the AFT position) produces a signal proportional in amplitude to the angular displacement, and in phase with the excitation voltage. This output voltage causes the pitch mode to compensate for a forward shift in the center of gravity. Counterclockwise rotation of C G TRIM control B102 (toward the FWD position) produces a proportional signal with a phase shift of 180 electrical degrees from the excitation voltage. This voltage causes the pitch mode to compensate for a shift in the center of gravity toward the tail of the helicopter. The effects of adjustment of C G TRIM control B102 are monitored on NULL INDIC meter M101. The rotor output, approximately 1/10 volt per degree of rotor displacement, is developed across resistors R105 and R106, with capacitor C103 providing phase correction. Resistors R104 and R103 and capacitor C102 form a load- and phase-shifting network for the pitch canceller output. Normally, a pitch cancelling signal is not present and a portion of the C G TRIM control output is applied to the pitch servo amplifier through resistor R104 and pin E of connector J5. If a pitch canceller signal appears as a result of a manual correction of the pitch attitude, a modified signal will be applied to the pitch channel.

h. YAW TRIM Control B101. YAW TRIM control B101 is a differential synchro used to modify the yaw displacement signal from the J2 compass system. The modified output signal causes the yaw mode to provide a heading change equal to the output of YAW TRIM control B101. The yaw displacement signal from the J2 compass system is fed through pins N, R, and P of connector J6 to the stator windings of the YAW TRIM control. When the rotor is at 0° angular displacement with respect to the stator, maximum coupling exists and the J2 compass signal feeds through YAW TRIM control B101 unchanged. The rotor output is connected through pins K, L, and M of connector J5 to the yaw synchronizer assembly in the control gyro and amplifier. When the rotor of YAW TRIM control B101 is manually rotated, the yaw displacement signal from the J2 compass system is modified, proportional to the degree of angular displacement.

This modified signal, when received by the yaw synchronizer assembly, causes the yaw channel to compensate for the signal by changing the heading of the helicopter. YAW TRIM control B101 is used during automatic flight to effect slight changes in the helicopter heading without disengaging the yaw channel. Each index mark on the front panel represents 1° of heading change. The control must be turned slowly, as a rapid rotation will cause the helicopter to skid while turning.

19. Control Gyro and Amplifier Assembly Model No. 1005N, Schematic Diagram Analysis

a. General. The control gyro and amplifier assembly converts mode displacement signals for application to servo motors which stabilize the flight of the helicopter. The control gyro and amplifier consists of a main chassis and the following subassemblies: vertical gyro assembly, multiple-channel amplifier assembly, yaw synchronizer assembly, 5-signal adjustment assembly, 12-signal adjustment assembly, and four servo amplifier assemblies (pitch, roll, yaw, and altitude). The following paragraphs provide detailed schematic analysis for each of the above mentioned subassemblies.

b. Main Chassis Assembly (fig. 73). The main chassis assembly contains a power distribution circuit, a time delay circuit, control relays for the autopilot system, an altitude control preamplifier circuit, a quadrature nulling circuit, a control transformer circuit, and a null indicator circuit.

(1) Power transformers T4, T5, and T6 are supplied with phase A of the 115-volt, 400-cycle, ac input to the control gyro and amplifier from the system AC-DC interlock relay through pin S of connector J2. The primary winding (1–5) of transformer T4 is tapped for 30-volt and 20-volt outputs. The 30-volt tap is connected to the wiper arm of NULL IND. CENT. potentiometer R602 in the 5-signal adjustment assembly through pin 8 of connector J21. This potentiometer provides a reference voltage for the null indicator circuit. In addition, 30 volts is applied to the altitude control through pin M of connector J3. The 20-

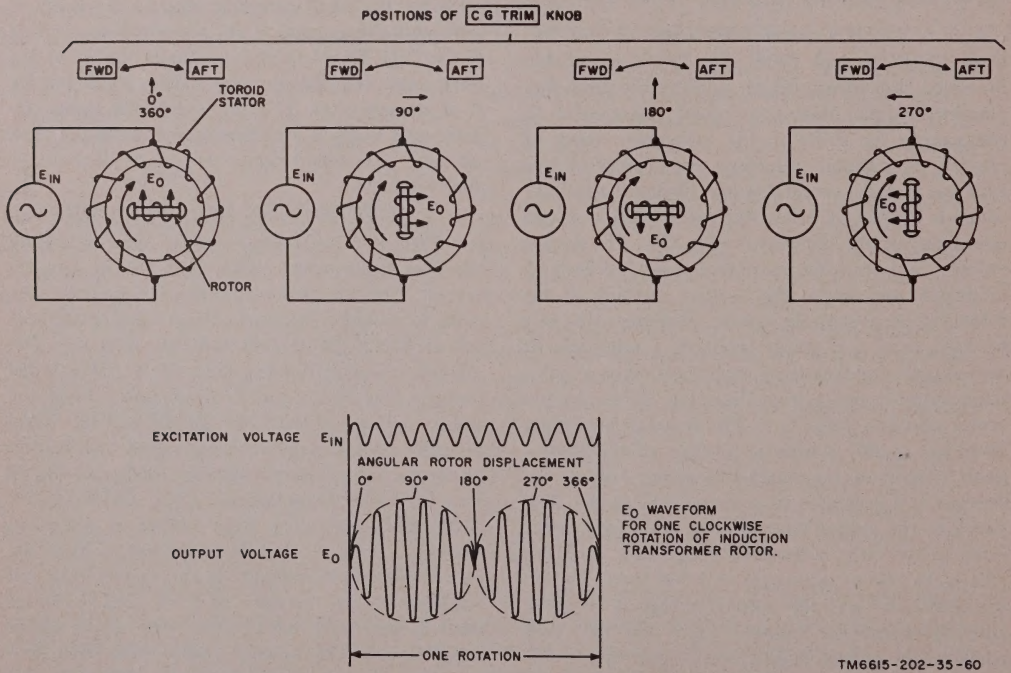


Figure 15. Operation of variable induction transformer (CG TRIM control B102).

volt tap is connected to the wiper arm of potentiometer R330 and one end of potentiometer R309, in the roll integrator, through pin 2 of connector J15. In addition, 20-volt excitation is applied to the field winding of the generator in the yaw synchronizer assembly through pin 7 of connector J23. The field winding of the motor is excited by the same 20 volts which passes through pin 4 of J23 from a phase-shifting network composed of capacitor C14 and resistor R28. The secondary winding of T4 supplies 1-volt excitation to the C G TRIM control in the control panel and to the roll and pitch cancellers through pin A of connector J4.

(2) The output of transformer T5 is applied directly to full-wave rectifier V1. The output of V1 is filtered by choke L1 and capacitor C18B. The +275-volt dc (B+) output is applied to all power amplifiers in the multiple-channel amplifier through pin 3 of connector J15; to pin 2 of erection delay relay K1 through series dropping resistor R52, and to the control windings of the magnetic amplifiers in the motor box through pin J of connector J3 which act as plate loads for the power amplifiers in mode servo amplifiers. The plate voltages for the mode servo amplifiers are reapplied to the control gyro and amplifier through pins A and B, C and D, E and F, and G and H of connector J3 distributed to the yaw servo amplifier through pins 7 and 8 of connector J11, the roll servo amplifier through pins 7 and 8 of connector J17, the pitch servo amplifier through pins 7 and 8 of connector J19, and the altitude servo amplifier through pins 7 and 8 of connector J13, respectively. B+ voltage is also applied to transformers T12 and T8 on the main chassis. The plate circuit of power amplifier V3B, in the yaw discriminator circuit, is supplied with +275 volts dc through one winding of coupling transformer T12, which acts as a plate load. Output winding 3–4 of transformer T8 drives the motor in the yaw synchronizer assembly. The drive voltage is supplied to the winding of the motor through normally closed contacts 13 and 14 of engage relay K3 and pin 3 of connector J23. If K3 is energized, the drive voltage apsses through make contacts 13 and 12 of engage relay K3 and contacts 10 and 11 of sync turn relay K5 and pin 3 of connector J23. The operation of this circuit is discussed in *d* below.

(3) The output of rectifier V1 is also applied to a voltage divider network consisting of dropping resistors R50 and R49, and capacitor C18A, and voltage regulator V4. The output of this network is a regulated +150 volts dc, which is supplied to the plates of all displacement preamplifiers in the servo amplifier subassemblies. In addition, it furnishes plate voltage for altitude preamplifier V2B through transformer resistor R25 and through transformer T10 to the plate of yaw discriminator V3A.

(4) Transformer T6 is an autotransformer with 60-volt and 15.5-volt taps. The 14.5-volt and 13-volt taps are not used. The 60-volt tap is used for fast erection of the gyro rotor. The stator of the *roll torquer* receives 60 volts ac, phase A, through normally closed contracts 13 and 14 of delay end relay K6 and pin 21 of connector J5 (CG&A). When rectifier V1 warms up sufficiently to energize erection delay relay K1, 60 volts ac is applied to the *pitch torquer* through contacts 7–8 of K6, 6–5 of K1, and pin 20 of connector J5 (CG&A). When time delay relay K9 is energized, delay end relay K6 is also energized through contacts 5–7 of K9. With relay K6 energized, normally closed contacts 13–14, and 7–8, open, removing the 60 volts from the roll and pitch torquers. In addition, normally open contacts 6–7 of relay K6 close and apply 15.5 volts ac to the roll and pitch torquers through closed contacts 6–5 of relay K1 and pin 20 of connector J5 (CG&A). The normal or operating voltage of the pitch and roll torquer motors is 15.5 volts ac. The 25-volt secondary winding on transformer T6 is used to supply filament voltage to rectifier V1.

(5) The altitude control preamplifier circuit on the main chassis assembly consists of altitude preamplifier V2B and transformer T9. The displacement signal from the altitude control is applied to the grid of V2B

through pin K of connector J3. Resistor R24 is a grid leak resistor, R23 provides cathode bias, and R25 is a plate load resistor. Capacitor C12 couples the signal to T9, and capacitor C13 is a transient suppressor. The amplified output of tube V2B is applied to the altitude servo amplifier through coupling transformer T9, closed contacts 6–7 of relay K7, closed contacts 12–13 of engage relay K4, and pin 9 of connector J12.

(6) The yaw discriminator circuit, composed of yaw discriminator V3, transformers T10, T11, and T12, and associated circuit components, and the power failure circuit, consisting of transistor Q1, transformers T2 and T3, and power failure relay K8, are not used in this equipment. Right turn relay K11 and left turn relay K10, in the turn circuit are also not used. However, normally closed contacts 4–5 on both relays are used to complete a circuit path through which sync turn relay K5 is energized.

c. Vertical Gyro Assembly (fig. 16). The vertical gyro assembly provides a stable reference from which the pitch and roll displacement signals are derived. The assembly is contained in an hermetically sealed container, pressurized by 1 atmosphere of helium. The vertical gyro assembly consists of three-phase inductive gyro motor B111, two displacement signal synchros B113 and B121 (pitch and roll, respectively), snubber solenoid L131, and an erection system which, in turn, consists of two split-phase torquer motors B131 and B112, and two gravity-sensing electrolytic switches S111 and S121.

(1) The three-phase inductive gyro motor is used to rotate the gyro rotor at approximately 22,000 revolutions per minute (rpm). Power for the motor is supplied directly from the 400-cycle, 3-phase, 115-volt electrical system of the helicopter through the system AC-DC interlock relay (fig. 24).

(2) Gimbal snubber L131 is used to keep the gyro gimbal locked when autopilot power is shut off. Phase A of the 115-volt ac input applied to the snubber solenoid through pin 9 of connector J5 is rectified and filtered by crystal diode CR131 and capacitor C131 to provide DC energizing voltage to the snubber solenoid, uncageing the gyro gimbals. With the gimbals uncaged, the gyro is free to rotate. The phase A voltage applied to gyro rotor B111, is reduced during the initial acceleration by applying the phase A voltage to the rotor through pin 4 of connector J5, gyro start resistor R131 to pin 5 of connector J5. From pin 5 of J5, the phase A voltage is applied through series dropping resistor R30 (fig. 73) and pin 3 of connector J5 (fig. 16). Gyro start resistor R131 reduces the current to the phase A winding, thus reducing phase A loading. Phase C of the 115-volt 400-cycle source is applied directly to the gyro motor through series dropping resistor R31 (fig. 73) and through pin 1 of connector J5 (fig. 16). The phase B winding of the gyro motor is grounded through pin 2 of connector J5 (CG&A) and loading resistor R32 (fig. 73).

(3) The gyro spin axis is erected to the vertical position by roll torquer motor B112 and pitch torquer motor B131. Transformer T6 (fig. 73) applies a 60-volt ac excitation voltage to roll torquer motor B112 through normally closed contacts 13–14 of delay end relay K6 and pin 21 of connector J5 (CG&A). After approximately 15 seconds, the +275-volt dc output of rectifier V1 energizes erection delay relay K1. With relay K1 energized, normally open contacts 6–5 close and the 60-volt ac excitation voltage is applied to pitch torquer motor B131 through normally closed contacts 7–8 of relay K6, closed contacts 6–5 of relay K1, and pin 20 of connector J5. In addition, with relay K1 energized, normally open contacts 4–3 close, shorting out gyro start resistor R131 (fig. 16) routing the 115-volt phase A input directly to gyro motor B111. Gyro rotation is prevented by applying erection voltage only to the roll torquer motor for the first 15 seconds, and then to the pitch torquer motor. The 60-volt ac excitation is needed to initially erect the gyro and bring it up to speed. After approximately 2½ minutes, contacts 5–7 of thermal time delay relay K9 (fig. 73) close and apply +28 volts dc to the windings of delay end relay K6 and sync turn relay K5 simultaneously. The energizing path

for sync turn relay K5 is from contacts 5–7 of relay K9, pins F, F, and J of connectors J4 (CG&A), J5, and J6 (control panel) (fig. 72), respectively, to the pilot's and copilot's pedal switches (fig. 84). If the pilot's and copilot's pedal switches are closed, +28 volts dc is returned to the coil of relay K5 (fig. 73) through pins L and H of connectors J6 and J5 (control panel) (fig. 72), pin H of connector J4 (CG&A) (fig. 73), and normally closed contacts 5–4 of left turn relay K10 and right turn relay K11. With relay K6 energized, normally closed contacts 8–7, and 13–14 open, removing the 60-volt ac fast level erection voltage from the roll and pitch torquer motors. In addition, normally open contacts 6–7 of relay K6 close, applying 15.5 volts ac excitation voltage to the pitch torquer motor through contacts 6–5 of K1 and pin 20 of J5. The roll torquer motor receives 15.5 ac energizing voltage from closed contacts 3–4 of relay K5 through pin 21 of J5. When a helicopter turn is executed, the pilot's or copilot's pedal switch opens and de-energizes sync turn relay K5. With K5 de-energized, contacts 3–4 open, removing the 15.5-volt low-level erection voltage from roll torquer switch S121. This is necessary to avoid any gyro deviation from the true vertical which would be caused by the electrolyte in switch S121 splashing from side to side, thus falsely unbalancing the bridge.

(4) The erection torquer motors are split-field inductive motors, using a rotor mounted on the gyro gimbals. The rotors of these motors do not rotate freely, but are turned through a small angle by the change in phase of the applied voltage. As the rotors turn, they mechanically precess the gimbals for erection. The roll and pitch torquers are controlled by gravity-sensing roll and pitch electrolytic switches S121 and S111, respectively. The gravity-sensing switch forms the variable leg of a bridge which includes the split field of the motor and phase shift capacitors C133 and C134. The electrolytic switch consists of a metallic cup partially filled with a low-resistance electrolyte, and capped with an insulating material. Three contact buttons are molded into this cup. The switch is mounted on the underside of the rotor housing so that when the gyro motor is perpendicular to the earth, the electrical resistance from each of the contacts through the electrolyte to the metal cup, which is grounded, is equal. Two of these contacts are along the roll axis, and two along the pitch axis. If the gyro rotor precesses along either the roll or pitch axis, the resistance between ground and each of the switch contacts in the axis involved varies differentially. By varying the area covered by the electrolyte and thus varying the resistance, the bridge circuit is unbalanced. The unbalanced bridge causes a phase shift through the capacitors in the bridge. The resultant phase shift unbalances the current through the field windings, causing the rotor to precess the gimbal in a direction to keep the spin axis vertical.

(5) Roll and pitch synchros B121 and B113 develop the displacement signals which are applied to the roll and pitch servo amplifiers. The rotors of the synchros are excited by a 115-volt, ac, phase A signal applied directly from the AC-DC interlock relay through pin S of connectors J2 (fig. 73) and pins 7 and 24 of connector J5 (fig. 16). The stator is the signal source. The signal developed is an AC signal which is proportional to helicopter attitude. The amplitude of the signal determines the amount of displacement from the horizon; the phase determines the direction of displacement.

(6) The signal developed by pitch synchro B113 is applied to the pitch bridge on the main chassis assembly through pins 14, 15, and 16 of connector J5 (CG&A). The pitch bridge consists of resistors R33, R36, R37, and R38, and potentiometer R34 (fig. 73). When the rotor is displaced from the electrical zero position, a signal is induced in the stator, the amplitude and polarity of which is proportional to the angular displacement of the rotor. The output of the pitch bridge, which is taken off the wiper arm of potentiometer R34, is applied to the grid of the displacement preamplifier V201 in the pitch servo amplifier, through

closed contacts 9–10 of engage relay K4 and pin 9 of connector J18 (CG&A). Relay K4 is energized when ENG switch S101, on the control panel, is depressed. The pitch bridge converts the output voltage of the pitch synchro to the correct level and provides a single-phase input for the amplifier. When the helicopter is in level flight, that is, when it is not displaced from the pitch axis, the rotor of pitch synchro B113 is in the electrical zero position. In this position, no signal is developed in the stator; therefore, no signal is applied to the pitch servo amplifier.

(7) Roll synchro B121 operates on the same principle as the pitch synchro except that the rotor is angularly displaced when the helicopter is displaced from the roll axis. The signal from roll synchro B121 is applied to the roll bridge, which consists of resistors R40, R42, R43, and R44, and poteniometer R41. The output of the bridge is applied to the secondary winding of output transformer T302B in the roll integrator circuit (*e* below) of the multiple channel amplifier (fig. 74) through pin 7 of J14. The signal is combined with the output of modulator V301 and applied to displacement preamplifier V201B in the roll servo amplifier (fig. 75) through pin 9 of J14, closed contacts 6–7 of engage relay K4, and pin 9 of J16 (fig. 73).

d. Yaw Synchronizer Assembly (fig. 17). The yaw displacement signal is applied to the stator of the yaw synchro. This displacement signal is generated in the helicopter J2 compass system. The induced rotor output signal of the yaw synchro is applied to the displacement input circuit in the yaw servo amplifier (fig. 76) through pin 5 of connector J22, resistor R6 (fig. 73), contacts 9–10 of yaw transfer relay K2, and pin 9 of connector J10. The yaw channel operates under two conditions; the *standby* condition and the *engaged* condition.

(1) *Standby condition.* When the yaw signal channel is in standby condition, the yaw synchronizer assembly operates to null the yaw displacement signal. This provision is necessary to stabilize the helicopter on a new heading. The displacement signal from the J2 compass system is coupled in series with the YAW TRIM synchro in the control panel to the stator of the yaw synchro in the yaw synchronizer assembly (fig. 17). The displacement signal is applied to the stator of the yaw synchro through pins 1, 2, and 3 of connector J22, from pins K, L, and M of connector J4 on the main chassis (fig. 73). Any change in magnetic flux in the yaw trim stator due to a displacement signal from the J2 compass system, or to a YAW TRIM adjustment, induces a voltage in the yaw trim stator. Yaw synchro rotor voltage is supplied by transformer T1 of the quadrature nulling circuit, and coupled in series with the output winding of the velocity generator pins 5 and 2 of connectors J21 and J23, respectively, and in series with the input stage of the turn amplifier through pins 1 and 6 of connectors J23 and J14 respectively. The quadrature nulling circuit consists of a bridge circuit formed by resistors R3 and R5 on the main chassis assembly, and VEL. GEN. QUAD. potentiometer R603 in the five-signal adjustment assembly (fig. 18). The circuit is used to cancel out the undesired quadrature component of the velocity generator voltage. The quadrature component is a voltage which is 90° out of phase with the desired velocity generator voltage. The bridge circuit is excited through transformer T1. The primary of T1 is excited from the 20-volt top of power supply transformer T4 through capacitor C14 and resistor R28. Capacitor C14 and resistor R28 cause the excitation voltage present at the primary of transformer T1 to lead the phase A input voltage by 90°. The voltage induced in the secondary of transformer T1 is applied to the bridge through dropping resistors R2 and R4. The quadrature nulling voltage developed across the VEL. GEN. QUAD potentiometer is applied from the wiper arm through pin 5 of J21 (fig. 18) to the generator in the yaw synchronizer assembly (fig. 17) through pin 2 of J23. The quadrature nulling voltage and the generator output voltage combine across generator winding 5–7, forming a yaw displacement signal, which is applied through pin 1 of J23 and pin 6 of J14 (fig. 73) to the grid of turn preamplifier V303 in the multiple channel amplifier as-

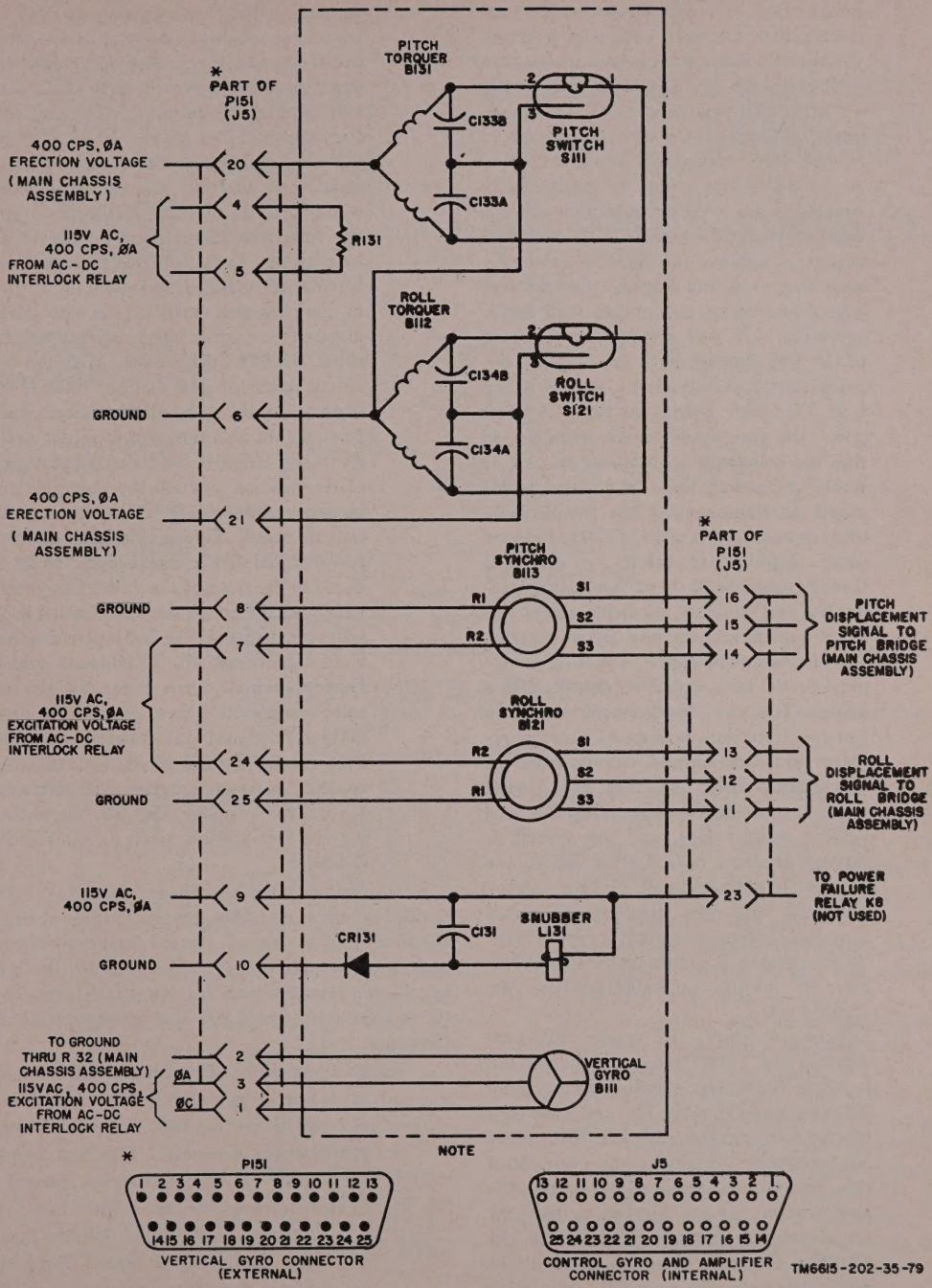


Figure 16. Vertical gyro assembly, schematic diagram.

sembly (fig. 74). The output of the turn preamplifier is applied back as a feedback voltage to control winding 2–1 of the turn motor through pin 8 of J15, transformer T8 (fig. 73), contacts 13–12 of engage relay K3, normally closed contacts 10–11 of sync turn relay K5, and pin 3 of connector J23. The motor is mechanically coupled to the velocity generator and the rotor of the yaw synchro. The generator output is applied through the turn preamplifier, as is the original displacement signal, and serves to dampen turn motor operation. The turn motor turns the rotor of the yaw synchro until the coupling between rotor and stator is at a null, at which time the rotor output is zero. At this point, the yaw signal circuit is nulled, so that the helicopter is stabilized in yaw at whatever heading the yaw channel is engaged. In standby condition, the displacement signal input to pin 9 of J10 of the yaw servo amplifier (*f* below) is grounded through contacts 10–11 of yaw transfer relay K2, and therefore, no displacement signal is applied into the yaw signal channel. The displacement signal, however, is applied to the turn circuit as described in *c* above. The yaw displacement signal, in *standby* condition, is applied through resistor R6 to two parallel circuits from the yaw synchro rotor: one circuit is to ground through contacts 14–13 of relay K2, and loading resistor R51, and one circuit is through contacts 8–7 of relay K2 to the quadrature nulling circuit. During standby operation, any yaw displacement signal from the J2 compass system serves to drive the turn motor. The turn motor then drives both the velocity generator and the yaw synchro rotor.

(2) *Engage condition.* To engage the yaw channel, the ENG button on the control panel is depressed, causing engage relay K3, yaw transfer relay K2, and sync turn relay K5 to energize (fig. 73). With relay K2 energized, normally open contacts 10–9 close and the displacement signal from the yaw synchro rotor is applied to the yaw servo amplifier through pin 9 of J10. In addition, normally closed contacts 13–14 open, breaking the ground connection through loading resistor R51, and the full current of the displacement signal is fed to the servo amplifier. With relay K3 energized normally open contacts 12–13 close, transferring the output of turn amplifier transformer T8 to contact 10 of relay K5. Since relay K5 becomes energized at the same time as relay K3, normally closed contacts 10–11 of relay K5 break to open the turn amplifier output circuit to the turn motor. Sync turn relay K5 and yaw transfer relay K2 are energized at all times in the engaged condition, except during manually controlled turns (when the tail rotor pedals are depressed). With the turn circuit open, the yaw synchro rotor is stationary so that the displacement signal from the J2 compass system is not nulled as in the standby condition. Adjustment of the heading through the autopilot may be made by the YAW TRIM knob on the control panel. Turing this knob causes a proportional displacement signal to be induced in the rotor of the yaw trim synchro, which is fed through the yaw channel in the same manner as is the helicopter displacement signal from the J2 compass system. During manual turns made by the tail rotor pedals, the yaw channel is automatically placed in standby condition. Pressure on any one of the four tail rotor control pedals de-energizes sync turn relay K5 and yaw transfer relay K2, thus switching the yaw circuits back to the standby condition.

e. Multiple-channel Amplifier (fig. 74). The multiple-channel amplifier consists of three circuits: the turn amplifier circuit, the roll integrator circuit, and the yaw synchronizer circuit. Since the yaw synchronizer is not used in this installation, only the turn amplifier and roll integrator circuits are discussed.

(1) *Turn amplifier.* The turn amplifier is used in the yaw signal circuit to provide a control voltage for the turn motor in the yaw synchronizer assembly. The turn amplifier is used only when the yaw channel is in standby condition as described in *d*(1) above. In the standby condition, the modified yaw displacement signal from the generator in the yaw synchronizer assem-

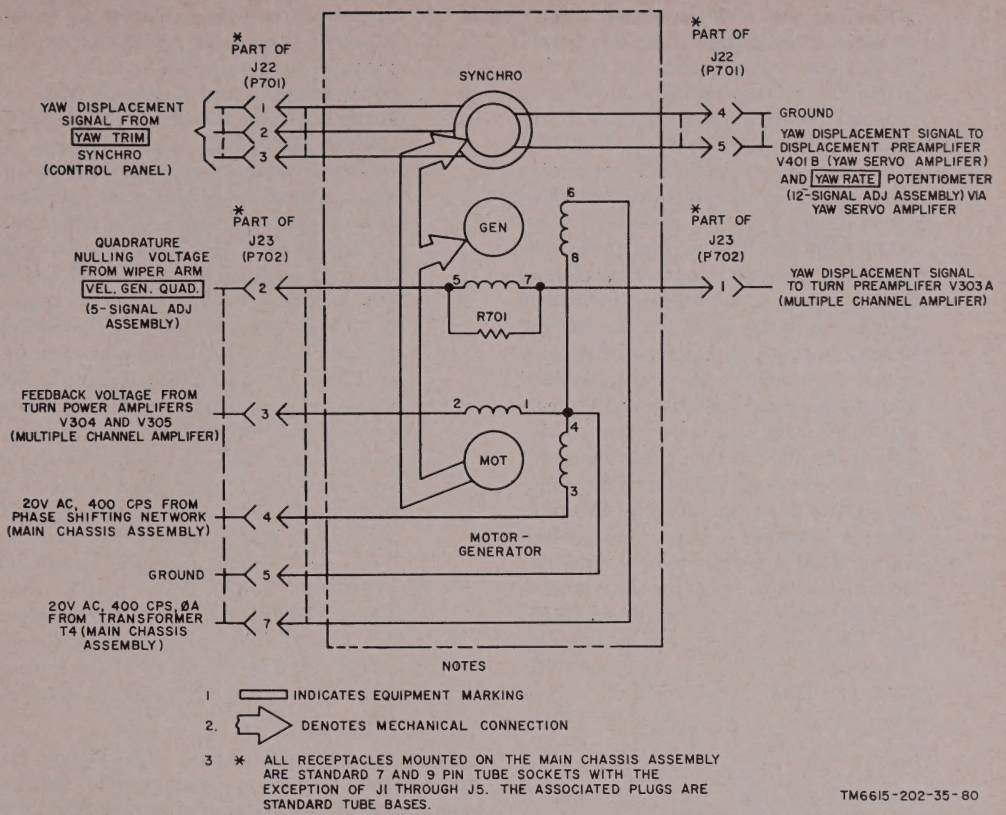


Figure 17. Yaw synchronizer assembly, schematic diagram.

bly is applied to the grid of turn preamplifier V303A through pin 6 of connector J14. The amplified signal is then applied to the grid of V303B through coupling capacitor C311. The signal developed across plate load resistor R325 is decoupled by capacitor C312. The amplified output of V303B is applied to the grids of amplifiers V304 through coupling capacitor C313 and to the grids of V305 through capacitor C113 and resistor R329. Resistor R329 is used for grid limiting; resistors R321, R322, and R326 are used for cathode biasing; and resistors R328 and R327 are grid leak resistors. Resistor R323 is the plate load resistor for tube V303B. The output of power amplifiers V304 and V305 is applied through pin 8 of connector J15 to the turn motor in the yaw synchronizer assembly via turn output transformer T8 (fig. 73), contacts 13–12 of engage relay K3, normally closed contacts 10–11 of sync turn relay K5, and pin 3 of connector J23. In the engaged condition, sync turn relay K5 is energized. With K5 energized, normally closed contacts 10–11 open, thus removing the output of the turn amplifier from the turn motor.

(2) *Roll integrator.* The roll integrator circuit is used to introduce a time lag in the roll canceller displacement signal and to couple the canceller signal, in series with the roll displacement signal, to the roll servo amplifier. The roll canceller displacement signal is coupled to the roll integrator through transformer T301. Because of the rate network in the roll servo amplifier (*f* below), which derives the rate of cyclic stick

motion, the roll canceller signal must be delayed in anticipation of the rate circuit. The lag time is greater than the lead time so that the tendency for inducing vibration (ground resonance) is minimized. If the voltage across terminals 1 and 2 of T301 is zero, the currents in the two loops of the discriminator circuit are equal but opposite in phase. Thus, the voltage across resistors R305 and R306 is zero. If the voltage across terminals 1 and 2 of transformer T301 is not zero, the voltages induced in both halves of the secondary winding will be equal in amplitude but opposite in phase so that the current in one loop is increased over the no-signal condition and the current in the other loop is decreased. A difference of potential then exists across the network consisting of resistors R305, R330, and R306. Since the 20-volt, 440-cycle, phase A reference voltage from potentiometer R330 is greater than the voltages induced in both halves of the secondary, on the next half-cycle neither diode CR301 nor CR302 passes current and no difference of potential exists across resistors R305, R330, and R306. Thus, when the voltage across the primary of transformer T301 is of the same phase as the 20-volt reference voltage, a pulsating dc voltage is developed across resistors R305, R330, and R306. If the primary voltage is of the opposite phase or 180° out of phase with the 20-volt phase A reference, then the dc voltage developed across resistors R305, R330, and R306 is of opposite polarity. The magnitude of the voltage depends upon the displacement of the cyclic stick from neutral and the polarity depends upon the direction of movement, left or right. The voltage across resistors R305, R330, and R306 is applied to a filter network consisting of capacitors C301 and C302. These capacitors provide some filtering of the undesired ripple components. Resistors R303 and R304 and capacitor C303 provide the time delay which smooths out the movement of the cyclic stick. If the cyclic stick is given a short, rapid displacement, a dc voltage is almost immediately developed across resistors R305, R330, and R306, but it takes approximately 6 to 8 seconds to change capacitor C303 to 63 per cent of its final value, so that until C303 is charged, most of the voltage is across resistors R303 and R304. Thus, even though the voltage across resistors R305, R330, and R306 rises instantly, it requires time before this voltage is available at the grids of modulator V301. It is necessary to reconvert the roll canceller displacement signal back to a 400-cycle signal by modulating it with a 20-volt ac 400 cps, phase A reference voltage applied to the grids of modulator V301 through pin 2 of connector J15 and control potentiometer R309. The modulated roll canceller displacement signal is then combined with the vertical gyro displacement signal in output transformer T302B, and applied to the roll servo amplifier through pin 9 of J14. Capacitor C303 determines polarity, by biasing one tube more positively than the other. The output voltage developed across the primary of roll integrator output transformer T302B is a 400-cycle voltage which has an amplitude proportional to the displacement of the cyclic stick, and a phase proportional to the direction of displacement.

f. Servo Amplifier Assemblies (figs. 75 and 76). The four servo amplifier assemblies plug into the main chassis of the control gyro and amplifier. The circuits of the pitch, roll, and altitude servo amplifiers (fig. 75) are identical except for component values and reference designations of the yaw servo amplifier (fig. 76). In the following discussion, all components pertaining to the yaw servo amplifier are shown in parentheses. Since the four servo amplifiers are identical, only the roll servo amplifier is discussed below.

(1) *Displacement preamplifier, input circuit.*

(*a*) *Roll displacement signal* (fig. 75). The roll displacement signal plus the signal from the roll integrator is applied to the grid of displacement preamplifier V201B from roll integrator output transformer T302B in the multiple channel amplifier assembly (fig. 74), through pin 9 of connector J14, contacts 6–7 of relay K4, and pin 9 of connector J16. In addition, this signal is applied to ROLL RATE potentiometer R505, in the 12-signal ad-

justment assembly (fig. 19), through pin 8 of J16 and pin 4 of J7. The voltage tapped off potentiometer R505 is applied to the grid of rate preamplifier V201A (fig. 75) through pins 3 and 7 of connectors J7 and J16.

(*b*) *Pitch displacement signal* (fig. 75). The pitch displacement signal is applied to the grid of displacement preamplifier V201B from the wiper arm of potentiometer R34 in the pitch bridge (fig. 73), through contacts 9–10 of relay K4 and pin 9 of connector J18. In addition, this signal is applied to PITCH RATE potentiometer R508 through pin 8 of connector J18 and pin 4 of connector J8. The voltage tapped off potentiometer R508 is applied to the grid of rate preamplifier V201A through pins 3 and 7 of connectors J8 and J18, respectively.

(*c*) *Altitude displacement signal* (fig. 75). The altitude displacement signal is applied to the grid of displacement preamplifier V201B from altitude control preamplifier transformer T9 on the main chassis (fig. 73), through closed contacts 6–7 of relay K7, contacts 12–13 of engage relay K4, and pin 9 of connector J12. This signal is also applied to ALTITUDE RATE potentiometer R511, through pins 8 and 4 of connectors J12 and J9, respectively. The voltage tapped off potentiometer R511 is applied to contact 5 of relay K7 through pin 3 of connector J9. Since the altitude mode is engaged at a zero rate of climb, relay K7 is energized, normally closed contacts 5–4 are open, and the altitude rate signal is open-circuited. With relay K7 energized, contacts 4–3 close, grounding the grid of altitude rate preamplifier V201A through pin 7 of connector J12. The rate circuit in the altitude servo amplifier is not used in order to prevent the altitude servo motors from being driven by the periodic changes in air pressure caused by the downblast from the main rotor blades as they rotate. These air pressure variations are transmitted to the pressure-sensitive element in the altitude control through a static port which is located directly below the main rotor blades. If the rate signal were used, the flight of the helicopter would be erratic. With the helicopter in level flight, the rotor element in the altitude control is in neutral or zero position and the output from the rotor element is zero. If the helicopter changes altitude in response to external forces, the pressure-sensitive element will respond to the change in barometric pressure and actuate the clutch which, in turn, will move the rotor element.

(*d*) *Yaw displacement signal* (fig. 76). The yaw displacement signal is applied to the grid of displacement preamplifier V401B from the rotor of the yaw synchro in the yaw synchronizer assembly through pin 5 of connector J22, resistor R6, contacts 9–10 of yaw transfer relay K2, and pin 9 of connector J10. In addition, this signal is applied to YAW RATE potentiometer R502 through pins 8 and 4 of connectors J10 and J6, respectively. The voltage tapped off potentiometer R502 is applied to the grid of rate preamplifier V401A through pins 3 and 7 of connectors J6 and J10, respectively. In the standby condition, relays K2 and K4 are de-energized and the above signal paths are grounded.

(2) *Displacement preamplifier, output circuit* (fig. 75 or 76). The output of displacement preamplifier V201B (V401B) is taken across plate load resistor R204 (R404) and applied to the primary of transformer T202 (T402) in the mixer and discriminator circuit through coupling capacitor C203 (C403). The output of rate preamplifier V201A (V401A) is coupled through capacitor C202 (C402) to parallel grids of rate discrimniator V202 (V402). Both sections of the preamplifier stage of the servo amplifier operate as class A amplifiers.

(3) *Rate discriminator V202 (V402)* (fig. 75 or 76). AC voltages, of opposite phase, from transformer T201 (T401) are applied to the plates of rate discriminator V202 (V402). When there is no rate signal applied to the grids of V202 (V402), the plate currents through load resistors R207 and R208 (R407 and R408) are equal and

there is no potential difference between the outputs at coupling capacitors C206 and C207 (C406 and C407). However, when an input rate signal of some phase and magnitude is applied to the grids of rate discriminator V202 (V402) from rate preamplifier V201A (V401A), the discriminator acts as a grid-controlled rectifier. Depending upon the phasing of the 115-volt ac, phase A reference voltage applied to transformer T201A (T401A), either tube V202A (V402A) or tube V202B (V402B) conducts. A dc potential difference is developed between capacitors C206 and C207 (C406 and C407). The discriminator circuit compares the phasing of the input rate signal to the phase A reference voltage from the primary of transformer T201 (T401) and, from this comparison, applies a DC signal to mixer-discriminator V203 (V403). The polarity of this signal indicates the direction as well as the degree of displacement of the helicopter.

(4) *Rate output circuit and filter network* (fig. 75 or 76). The output of the discriminator circuit is applied to a derived rate circuit and filter network. The rate circuit consists of capacitors C206 and C207 (C406 and C407) and resistors R209 and R210 (R409 and R410). The rate circuit derives an output voltage which is proportional to the rate of change of the input voltage. The dc output voltage from the discriminator circuit is applied across capacitors C206 and C207 (C406 and C407). Thus, there is a voltage across resistors R209 and R210 (R409 and R410) only when there is a change in voltage at the output of the discriminator circuit. Capacitors C206 and C207 (C406 and C407) charge and discharge in accordance with this change in voltage. Since the change in polarity reflects a change in the direction of displacement, the polarity of the voltage across resistors R209 and R210 (R409 and R410) reflects the rate of displacement. The reactances of C206 and C207 (C406 and C407) vary inversely with the rate of change in the polarity of the discriminator signal, so that the faster the helicopter is displaced, the greater the voltage across resistors R209 and R210 (R409 and R410). The rate circuit, therefore, provides a rate signal reflecting both the direction and rate of displacement. The filter circuit consists of resistors R211 and R212 (R411 and R412) and capacitors C208 and C209 (C408 and C409). At higher frequencies, the reactances of capacitors C208 and C209 (C408 and C409) are negligible, and most of the high-frequency components contained in the signal are dissipated by resistors R211 and R212 (R411 and R412). Thus, the filter network serves to eliminate high-frequency noise voltages, radio-frequency voltages, and transient signals.

(5) *Mixer-discriminator V203 (V403)* (fig. 75 or 76). The *rate* signal voltage from the filter network is applied to the grids of mixer-discriminator V203 (V403). The *displacement* signal is coupled in series with the rate signal voltage through transformer T202 (T402). The primary of transformer T202 (T402) is excited by the output of the displacement preamplifier. Both sections of tube V203 (V403) are biased near cutoff. One secondary of transformer T201 (T401) is in each plate circuit of V203 (V403) but, unlike the secondaries in the plate circuit of the rate discriminator ((3) above), these are in phase. With both rate and displacement signals combined at the grids, the resultant output across resistors R216 and R217 (R416 and R417) is the sum of the two signal input voltages. Capacitors C211 and C212 (C411 and C412) reduce any ripple components. Mixer-discriminator V203 (V403) thus combines the rate and the displacement signals and converts the resultant to a varying dc signal which is proportional to the direction, degree, and rate of helicopter displacement.

(6) *Power amplifiers V204 (V404) and V205 (V405).* The output of tube V203 (V403) is coupled to the parallel grids of power amplifiers V204 (V404) and V205 (V405) through parasitic oscillation suppressing resistors R222, R223, R224, and R225 (R422, R423, R424, and R425). The amplifiers operate as conventional class AB_2 amplifiers, and provide the power required to operate the associated magnetic ampli-

fier in the motor box. The gain of the power amplifiers is determined by a quiescent current potentiometer R226 (R426) and a voltage divider network composed of resistors R218 (R418) and R219 (R419). The potentiometer and resistors provide cathode bias voltage for the power amplifiers.

g. Five-signal Adjustment Assembly (fig. 18).

(1) *BAR. ALT. PRE-AMP potentiometer R605.* Potentiometer R605 sets the gain of altitude control preamplifier V2 on the main chassis by biasing the cathode with respect to ground. One end of the potentiometer is connected to the cathode of tube B2 through pin 5 of connector J20; the wiper arm of the potentiometer is grounded through pin 4 of connector J20.

(2) *VEL. GEN. QUAD potentiometer R603.* Potentiometer R603 adjusts the quadrature nulling circuit (*d*(1) above). The quadrature nulling voltage is applied to the generator from the wiper arm of potentiometer R603 through pin 5 of connector J21. The 20-volt AC, 400 cps, phase A reference voltage is supplied to the potentiometer from transformer T4 on the main chassis through pins 4 and 6 of J21.

(3) *NULL IND. CENT. potentiometer R602.* Potentiometer R602 centers the NULL INDIC meter by balancing the voltage applied through pins 9 and 7 of connector J21, resistors R1 and R26, and rectifiers CR6 and CR7 on the main chassis. The 30-volt tap of power transformer T4 is connected to the wiper arm of potentiometer R602 through pin 8 of connector J21. By electrically centering the wiper arm of potentiometer R602, the needle of the NULL INDIC meter is centered.

(4) *NULL IND. SENS. potentiometer R601.* Potentiometer R601 adjusts the sensitivity or response rate of the NULL INDIC meter. The NULL IND. SENS. potentiometer is in series with the voltage applied to the NULL INDIC meter from the NULL IND. CENT. potentiometer.

(5) *ALT. RESET potentiometer R604.* Not used.

h. Twelve-signal Adjustment Assembly (fig. 19). The 12-signal adjustment assembly contains three adjustment potentiometers for each mode (yaw, roll, pitch, and altitude). DISPL FEEDBACK potentiometers R503, R506, R509, and R512 set the level of the transducer feed-back signals to properly cancel the displacement signals. RATE potentiometers R502, R505, R508, and R511 set the gain of the rate preamplifiers in the servo amplifier subassemblies (*f* above). DISPL potentiometers R501, R504, R507, and R510 set the gain of the displacement preamplifiers in the servo amplifier subassemblies by adjusting the feedback signal applied to the cathodes of the displacement preamplifiers from the tachometer generator of the appropriate servo motor assembly (fig. 20).

20. Motor Box Assembly Model No. S1645–61145–1, Schematic Analysis (fig. 77)

a. General. The motor box connects the servo motors to the autopilot circuits. The motor box receives varying DC displacement signals from the control gyro and amplifier. The DC input signals control the ac output which, in turn, controls the rotation of the servo motors. The motor box contains a magnetic amplifier for each channel of the autopilot, a transducer transformer, and the necessary circuit components and wiring. The motor box panel also contains test switches and adjustment potentiometers.

b. CHANNEL DISENGAGE Switches. Power is applied to CHANNEL DISENGAGE switches S4, S6, S7, S8, and S9, marked PITCH, ROLL, YAW, GOV., and ALT., respectively, from terminal 6 of the 115-volt ac, 400-cycle, phase A power bus. CHANNEL DISENGAGE GOV. switch S8 is not used in this autopilot. These switches provide the pilot or copilot with a means of disabling individual channels in case of a malfunction in one or more of the modes of operation, and still retain the use of the other channels. Operation of the CHANNEL DISENGAGE switches to the ON position applies power to the stator winding of the pitch, altitude, yaw, and roll servo motors through pin A of connectors J16, J17, J14, and J15, respectively.

c. Magnetic Amplifiers. Each magnetic amplifier is basically a saturable reactor consisting of two cores, an excitation, control, and output winding. Input voltage (115 volts AC, 400 cps, phase A) is applied from the time delay relay (fig. 24) to terminal 4 of the excitation windings of each magnetic amplifier from terminal 8 of the power bus. The

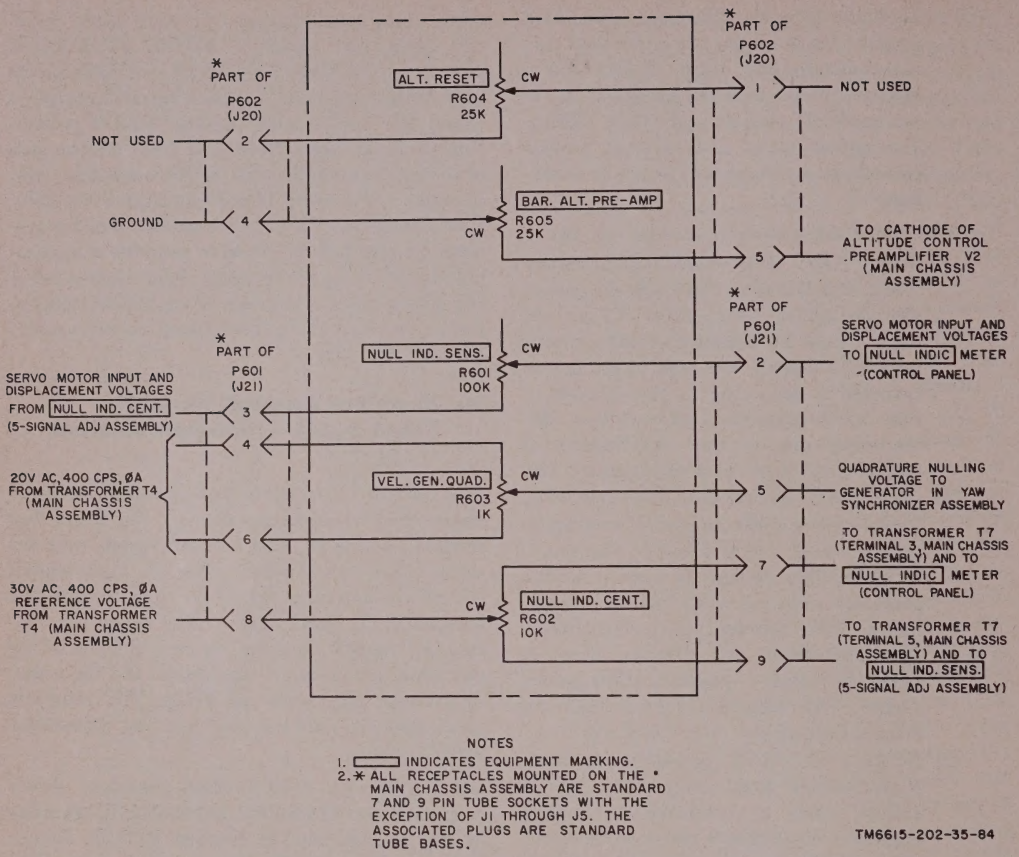


Figure 18. Five-signal adjustment assembly, schematic diagram.

115-volt AC, 400-cps, phase A input excites both cores of the magnetic amplifier. Output windings 6–7 are oppositely wound, one on each core, so that the induced voltages in the windings oppose each other and cancel out when there is no control voltage applied to the 1–3 control windings from the servo amplifier assemblies. Control windings 1–2 and 2–3 are also oppositely wound, one on each core. The control winding of the pitch, altitude, yaw, and roll magnetic amplifiers is applied from the associated servo amplifier in the control gyro and amplifier assembly through pins 12 and 13, 9 and 11, 16 and 17, and 14 and 15, respectively, of connector J18. The +275-volt dc circuit in the control gyro and amplifier provides plate voltage to the output stage of the servo amplifier which, in turn, controls the permeability of the cores of each magnetic amplifier. When a DC displacement signal voltage from a servo amplifier is applied across the control windings of one of the magnetic amplifiers, the change in voltage across the two windings with respect to the center tap is opposite in polarity. The relative polarity of the voltages in the two windings depends on the polarity of the output voltage from the servo amplifier. The difference in polarity of the voltages in the control windings tends to magnetically saturate one core of the magnetic amplifier, and decrease the magnetic flux in the other core. The differential in magnetic flux between the cores decreases the induced AC voltage in the output winding on one core, and increases it on the other, producing an AC differential across the output windings. The phase, amplitude, and duration of the 400-cycle output voltages are deter-

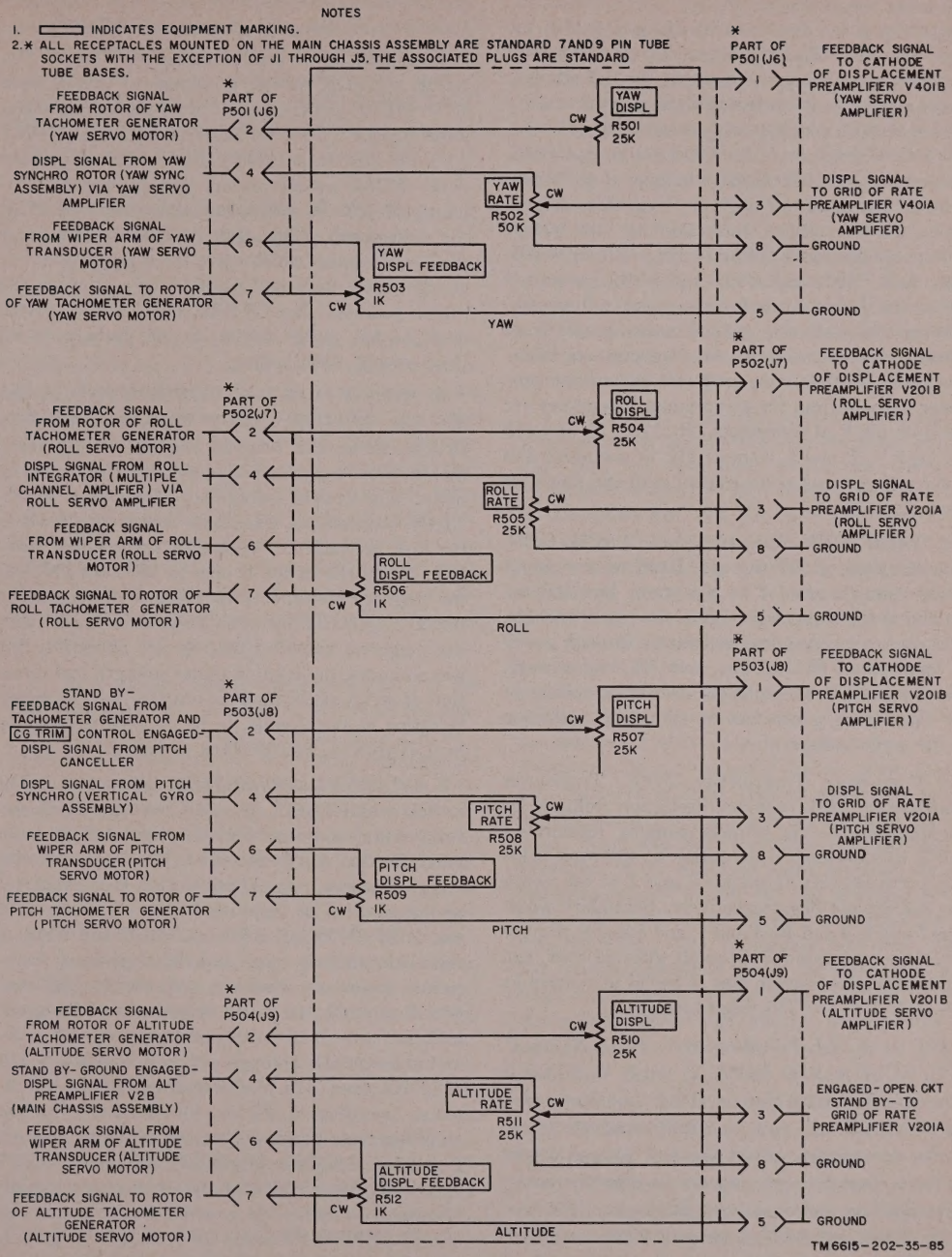


Figure 19. Twelve-signal adjustment assembly, schematic diagram.

mined by the polarity, voltage, and duration, respectively, of the displacement signal output of the servo amplifier. The AC differential output of each magnetic amplifier appears across the 6–7 winding and is applied to the rotors of their respective servo motors through pin B of connectors J16, J17, J14, and J15. Capacitors C111, C112, C109, and C110, connected across the output windings of the pitch, altitude, yaw, and roll magnetic amplifiers, respectively, provide phase correction to the output voltage. Capacitors C105 and C106, C107 and C108, C101 and C102, and C103 and C104, connected across the pitch, altitude, yaw, and roll control windings, respectively, prevent noise signals from affecting the operation of the magnetic amplifiers. The pitch, altitude, yaw, and roll tachometer generator outputs from the servo motor assemblies are fed from pin F of connectors J16, J17, J14, and J15 to pins 3, 1, 7, and 5, respectively, of connector J18 to the main chassis of the control gyro and amplifier assembly.

d. TACH. GEN. Potentiometers. TACH. GEN. potentiometers R105 through R108 receive input power from terminal 7 of the power bus and are applied to the stator windings of the pitch, altitude, yaw, and roll tachometer generators through pin D of connectors J16, J17, J14, and J15, respectively. The potentiometers adjust the excitation voltage of the tachometer generators to eliminate oscillation of the servo motors.

e. Transducer Transformer T101. Transducer transformer T101 provides excitation voltage for the transducers. The primary winding, terminals 1 and 2, is connected to the phase A, 400-cycle, 115-volt input between terminals 5 and 1 of the power bus and ground bus, respectively. Secondary windings 7 and 8, 9 and 10, 3 and 4, and 5 and 6, provide 8-volt ac excitation for the pitch, altitude, yaw, and roll transducers through pins H and K of connectors J16, J17, J14, and J15, respectively.

f. F. U. NULL Potentiometers. F. U. NULL P, F. U. NULL A, F. U. NULL Y, and F. U. NULL R potentiometers R101 through R104, connected across the pitch, altitude, yaw, and roll transducer transformer secondaries, adjust the null voltage output of their respective transducers to properly center corresponding servo motors. Resistors R134 and R135, R136 and R137, R130 and R131, and R132 and 133, connected across the F. U. NULL P, F. U. NULL A, F. U. NULL Y, and F. U. NULL R potentiometers, respectively, provide a zero reference level for the corresponding potentiometer.

g. OVERRIDE CHECK Switch S3. The OVERRIDE CHECK switch is connected across each F. U. NULL potentiometer. Placing the switch in either the LEFT FWD. DOWN INCR. or RIGHT AFT UP DECR. position shorts out one side of the F. U. NULL potentiometers and applies approximately 4 volts ac across the corresponding half of the transducers. This action produces transducer feed-back signals which drive the servo motors left or right from their null position, depending on the switch position. The OVERRIDE CHECK switch *must* be left in the center, or off, position at all times except when testing.

h. MOTOR INPUT-MOTOR POSITION Switch S2. The MOTOR INPUT-MOTOR POSITION switch checks the relative position of the servo motors with respect to the phase of the servo motor input. The switch, spring-held at MOTOR POSITION, connects the transducer feed-back signals to the null indicator for observing servo motor position. When the switch is held at MOTOR INPUT, the magnetic amplifier output signals are applied to the NULL INDIC meter on the control panel. Since the magnetic amplifier outputs are applied to the servo motors, the relative signal strength and direction of servo motor input is observed on the meter. Selection of the channel to be checked is provided by CHANNEL SELECTOR switch S1.

i. CHANNEL SELECTOR Switch S1. The switch contains an A, B, and C section. Each section contains a contact for each channel of the autopilot. Section A is connected to the output winding of each magnetic amplifier; section B is connected to the junction of resistors R134 and R135, R136 and R137, R130 and R131, and R132 and R133, in the pitch, altitude, yaw, and roll transducer transformer secondary windings, respectively; and section C is connected to the wiper arm of the pitch, altitude, yaw, and roll transducers on the servo motor assemblies through pin J of connectors J16, J17, J14, and J15, respectively. NULL INDIC meter transformer T7 on the control gyro and amplifier main chassis is connected across contacts 2 and 5 of MOTOR POSITION-MOTOR INPUT switch S2 through pins 23 and 24 of connector J18. Contact 1 of switch S2 is connected to the A side of CHANNEL SELECTOR switch S1 and to MOTOR VOLTAGE TEST jack TJ1 through resistor R138 and capacitor C113. Resistor R138 and

capacitor C113 compensate for the phase difference introduced in the magnetic amplifier circuit through the addition of transformer T7 in the NULL INDIC meter circuit on the main chassis of the control gyro and amplifier assembly. MOTOR VOLTAGE TEST jacks TJ1 and TJ2 provide a means of checking servo motor input.

21. Servo Motor Assembly Model No. S1665–61755, Schematic Diagram Analysis

(fig. 20)

a. General. The four servo motor assemblies are identical and each consists of a servo motor, a transducer, and mechanical linkage. The servo motor consists of a motor and a tachometer generator. The four transducers are, in effect, linear displacement potentiometers coupled to a tachometer generator. The pitch, altitude, yaw, and roll servo motors are controlled by the pitch, altitude, yaw, and roll magnetic amplifiers, respectively, in the motor box. The servo motors mechanically drive the tachometer generator and transducers and also actuate the helicopter flight control system through the auxiliary and yaw servo units.

b. Servo Motor. Stator windings 1 and 3 of the pitch, altitude, yaw, and roll servo motors are connected across pins A and C of connectors J16, J17, J14, and J15, respectively. The stator windings are connected to the helicopter phase A, 115-volt, 400-cycle supply through the CHANNEL DISENGAGE switches and the motor box power bus in the motor box. The TACH. GEN. potentiometers, in the motor box, adjust the excitation voltage of the pitch, altitude, yaw, and roll tachometer generators to approximately 4 volts ac. The pitch, altitude, yaw, and roll tachometer generator excitation windings (7 and 10) are connected across pins C and D of connectors J16, J17, J14, and J15, respectively. The 400-cycle control signal from the pitch, altitude, yaw, and roll magnetic amplifiers in the motor box is applied across pins B and C of connectors J16, J17, J14, and J15. The direction, speed, and amount of motor rotation is determined by the phase, voltage, and duration of the magnetic amplifier output. Each tachometer generator produces a maximum output of 3.2 volts per 1,000 rpm. The travel of each servo motor is limited to 10 turns. The pitch, altitude, yaw, and roll tachometer generator output is applied to pin F of connectors J16, J17, J14, and J15. The roll, yaw, and altitude tachometer generators apply a displacement signal of proper phase to the servo amplifiers in the control gyro and amplifier assembly through the associated DISPL potentiometer in the twelve-signal adjustment assembly to dampen servo motor rotation. The displacement signal from the pitch servo motor tachometer generator winding, however, is applied to the DISPL potentiometer in series with the C G TRIM voltage in the control panel and through closed contacts 3–4 of engage relay K4. The displacement signal, proportional to servo motor velocity, minimizes over shooting of the servo motors, and hence the helicopter flight controls. Connector J13 provides a cabling extension to the yaw servo motor assembly which is located on the tail rotor servo unit.

c. Transducer. The pitch, altitude, yaw, and roll transducers are connected across the pitch, altitude, yaw, and roll transducer transformer secondary windings in the motor box, through pins H and K of connectors J16, J17, J14, and J15, respectively. The pitch, altitude, yaw, and roll transducer wiper arms are mechanically coupled to their respective tachometer generator. The transducers are displaced from their null position by servo motor rotation whenever a displacement signal is initiated in one or more of the channels. The transducers then produce an ac feed-back signal which cancels the original displacement and rate signals applied to the associated servo amplifiers after the necessary corrections have been made. Servo motor rotation also produces a flight control correction proportional to the amount and rate of helicopter displacement. When the flight controls have stabilized the helicopter in its reference flight attitude, the displacement signal ceases, but the transducer feed-back signal still exists because the wiper arm is still displaced. The transducer feed-back signal then returns the servo motor (and also the transducer wiper arm) to the null (center) position, where they remain until another displacement signal is initiated. The pitch, altitude, yaw, and roll transducer signal is applied through pin J of connectors J16, J17, J14, and J15, respectively, to the PITCH, ALTITUDE, YAW, and ROLL DISPL FEEDBACK potentiometers, respectively, in the 12-signal adjustment assembly. Transducer output voltage, proportional to the linear displacement signal of the wiping contact, ranges from 0 at the null position to 4 volts ac when the servo motors are driven to their stop limit in either direction.

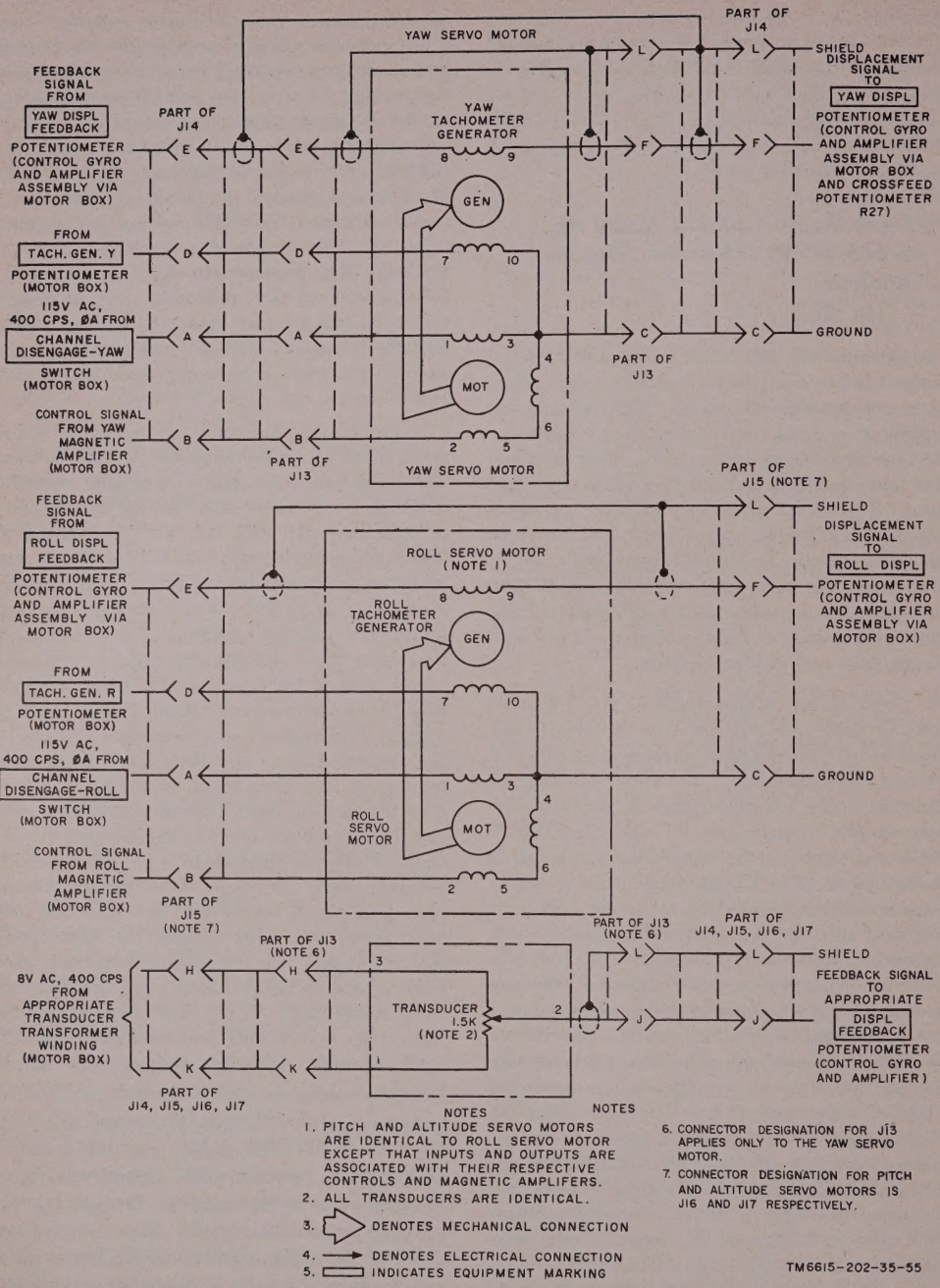


Figure 20. Servo motor assembly model No. S1665–61755, schematic diagram.

22. Control Stick Canceller Assembly Model No. 911D, Schematic Analysis
(fig. 21)

a. General. The pitch and roll cancellers are variable induction transformers, the rotors of which are mechanically coupled to the pilot's and copilot's cyclic control sticks. Movement of either cyclic control stick produces a signal from either the pitch or roll canceller rotor proportional, in phase and amplitude, to the direction and distance moved. This signal cancels the displacement signals generated in the pitch and roll channels of the autopilot when the pitch or roll attitudes are manually changed by the pilot or copilot.

b. Pitch Canceller. The stator (primary) of the pitch canceller variable induction transformer is a closed toroidal winding excited at two points, physically 180° apart, by a 1-volt 400-cps AC voltage applied to pins A and B of connector J8. This excitation voltage is supplied by the control gyro and amplifier through the control panel. The output voltage from the rotor (secondary) reflects in amplitude and phase the angular position of the rotor with respect to the stator. Detailed information pertaining to the operation of a variable induction transformer is given in paragraph 18*g*. The rotor of the pitch canceller is not free to rotate, but is turned by the cyclic control stick through an arc of approximately 60°. The center of rotor travel coincides with the zero null point, so that *fore* and *aft* movement of the pilot's or copilot's cyclic control stick from the neutral position turns the rotor of the pitch canceller clockwise or counterclockwise from the null point. Clockwise rotation produces an output voltage from the rotor proportional to the travel of the cyclic control stick and in phase with the excitation voltage. Counterclockwise rotation produces an output voltage from the rotor proportional to the travel of the cyclic control stick but 180 electrical degrees out of phase with the excitation voltage. The displacement signal resulting from a manual pitch altitude change is applied through pins C and D of connector J8 to the C G TRIM control in the control panel. The displacement and C G TRIM signals are then applied to the pitch servo amplifier through closed contacts 3–4 of engage relay K4 and the PITCH DISPL potentiometer. This signal cancels the pitch displacement signal generated by the pitch mode in response to the manual pitch attitude change.

c. Roll Canceller. The roll canceller is identical with the pitch canceller; therefore, the following discussion refers only to the mechanical coupling and application. The stator receives AC excitation voltage from the control gyro and amplifier (via the control panel) through pins A and B of connector J7. The rotor of the roll canceller is coupled to the pilot's and copilot's cyclic control stick. *Lateral* movement of either displaces the rotor and produces an output voltage proportional, in phase and amplitude, to the direction and amount of stick movement. The roll canceller signal is fed through pins C and D of connector J7 to the roll integrator circuit of the multiple channel amplifier in the control gyro and amplifier assembly via the control panel. This voltage cancels the roll displacement signal generated in the roll channel in response to the manual roll attitude change.

23. Altitude Control Assembly Model No. 2203G, Schematic Analysis
(fig. 22)

a. The altitude control provides an altitude displacement signal for the autopilot altitude channel. When a change in helicopter altitude takes place, a bellows assembly is actuated by the resulting change in barometric pressure. This change in pressure operates a differential transformer which develops the altitude signal. This displacement signal represents the helicopter change from an established altitude.

b. When the altitude mode of operation is engaged, the clutch coil is energized by +28 volts dc from the helicopter dc supply via the control panel through pin E of connector J9. Energizing the clutch coil engages a clutch mechanism which couples a mechanical linkage on the bellows assembly to a rotating variable inductive coupling bar. This bar is placed between the primary and secondary windings. In this manner, the inductive coupling between primary winding P1 and secondary winding S, and primary winding P2 and secondary winding S of the variable inductance transformer, is differentially varied. Current through the clutch coil is limited by a 120-ohm resistor. Primary windings P2 and P1 are connected in series and oppositely wound. The two primary windings are excited by phase A of the 30-volt, 400-cycle source through pin C of connector J9 from transformer T4 on the control gyro and amplifier main chassis. When the clutch coil is de-energized, the clutch mechanism

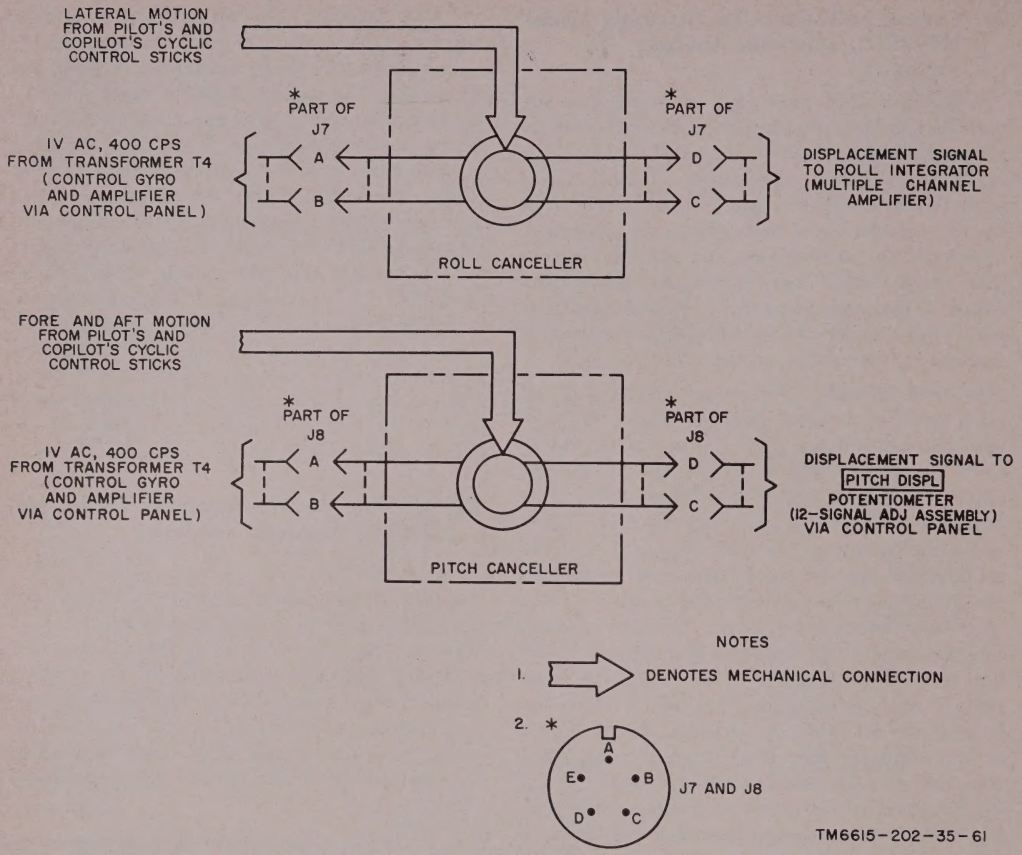


Figure 21. Control stick canceller assembly model No. 911D, schematic diagram.

is disengaged, leaving the coupling bar spring-held in its neutral position. With the variable inductive coupling bar in its neutral position, the inductive coupling between primary winding P1 and secondary winding S is equal to the coupling between primary winding P2 and secondary winding S. In this state, no voltage is induced in secondary winding S. When the clutch coil is energized and the clutch mechanism engaged, changes in barometric pressure, reflecting changes in helicopter altitude, rotate the variable inductive coupling bar from its neutral position, enabling a signal to be induced into secondary winding S. The signal polarity induced into secondary winding S is either phase A or phase A plus 180°, depending upon the direction of helicopter displacement with respect to the established altitude. This signal constitutes the altitude displacement signal and is applied to altitude control preamplifier V2 through pins A and B of connector J9. The level of the altitude signal is preset by a 5,000-ohm potentiometer in series with secondary winding S. Return for the 30-volt AC and +28-volt dc inputs is through pin D of connector J9.

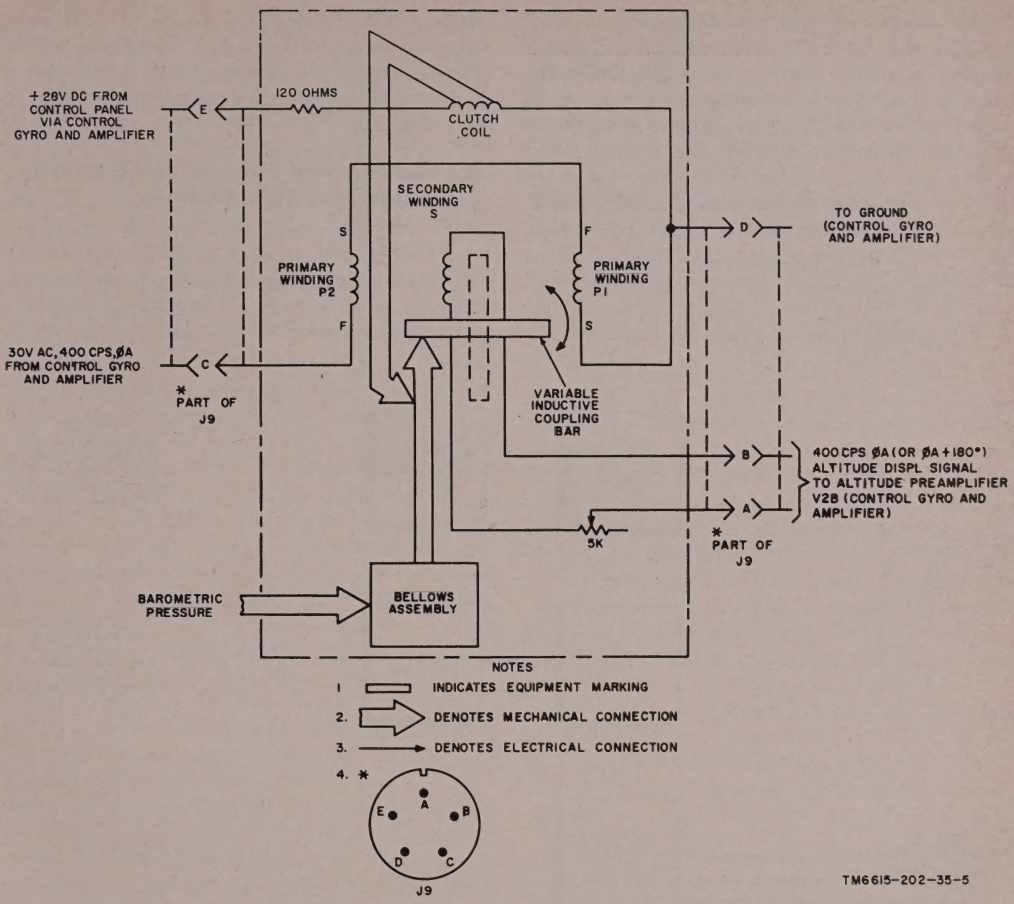


Figure 22. Altitude control assembly model No. 2203G, schematic diagram.

Section VI. FLIGHT CONTROL SWITCHES AND EXTERNAL RELAYS, AND POWER DISTRIBUTION CIRCUITS

24. Flight Control Switches and External Relays, Block Diagram Analysis

(fig. 23)

The 115-volt, 400-cycle, 3-phase and 28-volt, DC inputs from the helicopter electrical system are routed through the AC-DC interlock relay. This is a dual relay controlling application of both AC and DC power to the autopilot equipment. Failure of either input power source de-energizes the associated relay and removes the remaining power from the equipment. Phase A of the AC input is also applied to an open contact on the time delay relay. After equipment warm up, closing ENG switch S101 on the control panel energizes the emergency release relay and the heater of the time delay relay. At the end of approximately 2½ minutes, the contacts in the time delay relay close, applying phase A to the magnetic amplifiers in the motor box and also to the servo motors. Energizing power for the release relay is routed through the pilot's and copilot's normally closed AUTO STAB. RELEASE switches, located on the grip of their respective cyclic control

sticks. These switches are connected in series. Opening of either AUTO STAB. RELEASE switch removes ac power from the servo motors and the magnetic amplifiers in the motor box (after a slight time delay to return the servo motors to null position) and de-energizes all mode control relays in the control gyro and amplifier except delay end relay K6 and erection delay relay K1. Normally closed switches are located in the pilot's and copilot's right and left tail rotor control pedals. These switches are connected in series. Breaking the contacts of any one of the switches (when a pilot-controlled turn is desired) opens the yaw control channel, preventing opposition by the autopilot to the manual turn being executed by the pilot. Removing the feet from the tail rotor control pedals at the completion of a turn closes the pedal switches, re-engaging the yaw channel.

25. Flight Control Switches and External Relays, Schematic Analysis
(fig. 24)

a. The AC-DC interlock relay is a dual relay, one section of which operates on ac power and the other section on dc power. The 115-volt, 400-cycle, phase A and phase C voltage from the helicopter

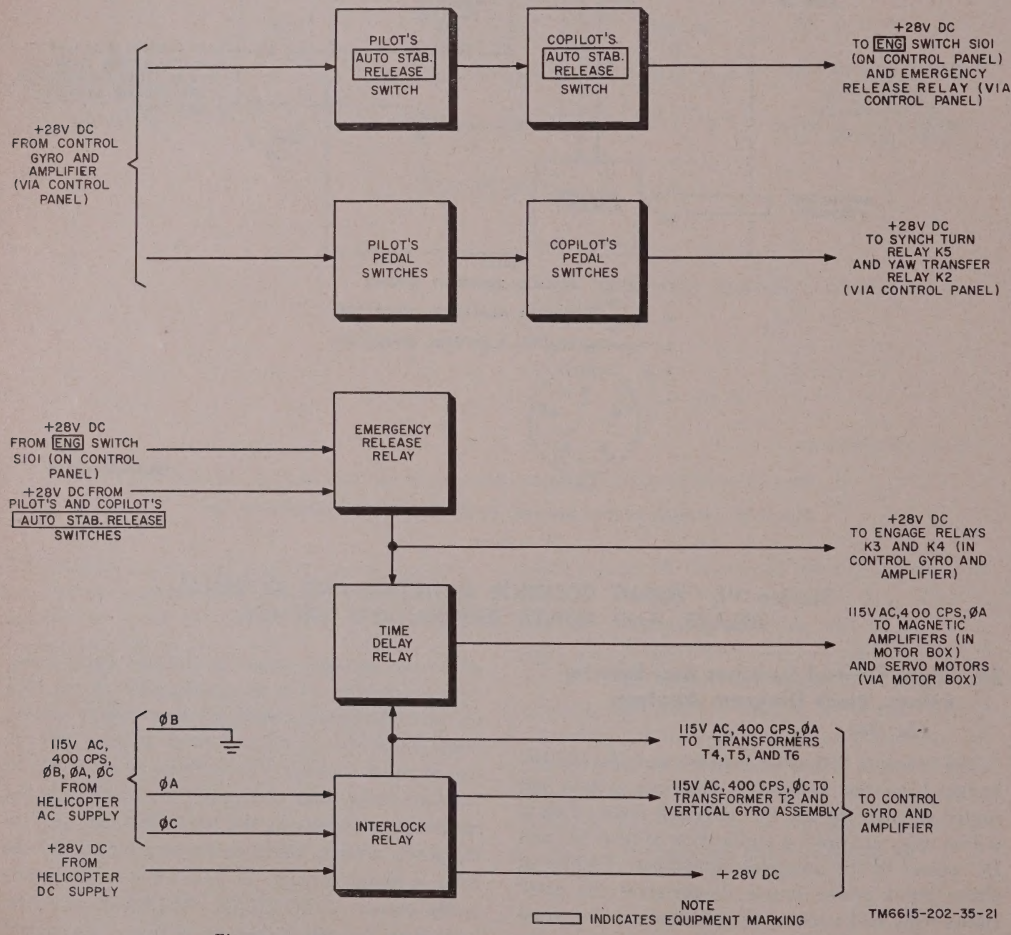


Figure 23. Flight control switches and external relays, block diagram.

ac supply energizes the coil of the ac section. Phase A and phase C are applied at the same time to normally open contacts of the DC section. Phase B voltage is at chassis ground. Closing the AUTO STABE circuit breaker energizes the dc section of the relay from the helicopter dc supply. Phase A and C voltages are applied through the relay contacts to the control gyro and amplifier. The +28-volt DC voltage is applied to the autopilot through previously closed contacts on the AC section relay. The AC-DC interlock relay is an equipment protection device which, upon failure of power to either section of the relay, removes power from the other section and thus renders the autopilot inoperative.

b. After the circuits of the equipment are warmed up and the vertical gyro comes up to speed, time delay relay K9 energizes to apply +28 volts DC to delay end relay K6 and to sync turn relay K5 through the normally closed contacts of relays K10 and K11 on the control gyro and amplifier. Closing of ENG switch S101 energizes the emergency release relay through pin *a* of connector J5 and the normally closed make-before-break contacts on the relay. The relay float makes before breaking the normally closed contacts, holding the relay energized through pin G of connector J5 on the control panel. Energizing the emergency release relay also applies +28 volts dc to the heater (terminals 2 and 3) of the time delay relay. After dc is applied, the contacts close, connecting phase A, 115-volt, ac power to the AC windings of the magnetic amplifiers in the motor box and to the servo motors. The AUTO STAB. RELEASE switches hold engage relays K3 and K4 in the control gyro and amplifier, the emergency release relay, and the time delay relay energized. In an emergency requiring disengagement of the autopilot, opening of either AUTO STAB. RELEASE switch de-energizes the release relay, the time delay relay, and the engage relays. When the release relay is de-energized, +28 v dc is removed from the heater in the time delay relay. After several seconds, the time delay relay de-energizes removing excitation voltage from the magnetic amplifiers in the motor box and from the servo motors. The time delay allows the servo motors to reach a null position before the ac excitation voltage is cut off. The 28-volt dc control voltage from delay end relay K6 in the control gyro and amplifier holds sync turn relay K5 and yaw transfer relay K2 energized through the pilot's and copilot's pedal switches. Opening of any one of these switches, during a pilot-controlled turn, de-energizes sync turn relay K5 and yaw transfer relay K2 placing the yaw control channel in standby condition. This prevents opposition to the turn by the autopilot. At the end of the pilot-controlled turn, the pedal switch is returned to its normally closed position. This re-energizes sync turn relay K5 and yaw transfer relay K2.

26. DC Power Distribution Circuits

(fig. 78)

a. The DC power distribution circuit for the autopilot are the B+ voltage distribution circuits and the 28-volt dc voltage distribution circuits. All B+ voltage used in the equipment is supplied from full-wave rectifier power supply stage V1, located in the control gyro and amplifier. The 28-volt DC supply is taken from the 28-volt DC bus of the helicopter power supply. In addition to supplying circuits within the control gyro and amplifier, B+ is distributed through integral receptacles to the pitch, altitude, roll, and yaw plug-in servo amplifiers and multiple-channel amplifier, and through cabling to the magnetic amplifiers in the motor box. The 28-volt dc voltage is distributed through the control gyro and amplifier from the AC-DC interlock relay to all filament circuits within the control gyro and amplifier and in the plug-in servo amplifiers and multiple-channel amplifier. The AC-DC interlock relay also supplies energizing power for all the relays (except erection delay relay K1), control panel indicator lamps, and the clutch coil of the altitude control.

b. The +28 volts DC from pin V of connector J2 on the control gyro and amplifier is applied to time delay relay K9. When contacts 5–7 of time delay relay K9 close, delay end relay K6 energizes. At the same time, +28 volts dc is applied through normally closed contacts 5–4 of engage relay K3, left turn relay K10, and right turn relay K11 to sync turn relay K5, energizing relay K5. The voltage from contact 7 of time delay relay K9 is also applied through pin F of connector J4 (control gyro and amplifier), and through pins F and J of connectors J5 and J6, respectively (control panel), to the pilot's and copilot's AUTO STAB RELEASE switches and pedal switches. The +28-volt dc control line from the AUTO STAB RELEASE switches is returned to the control panel through pin K of connector J6 and applied to the normally open contacts of ENG switch S101. A +28 volts dc holding voltage is applied to contact 6 of engage relay K3 in the con-

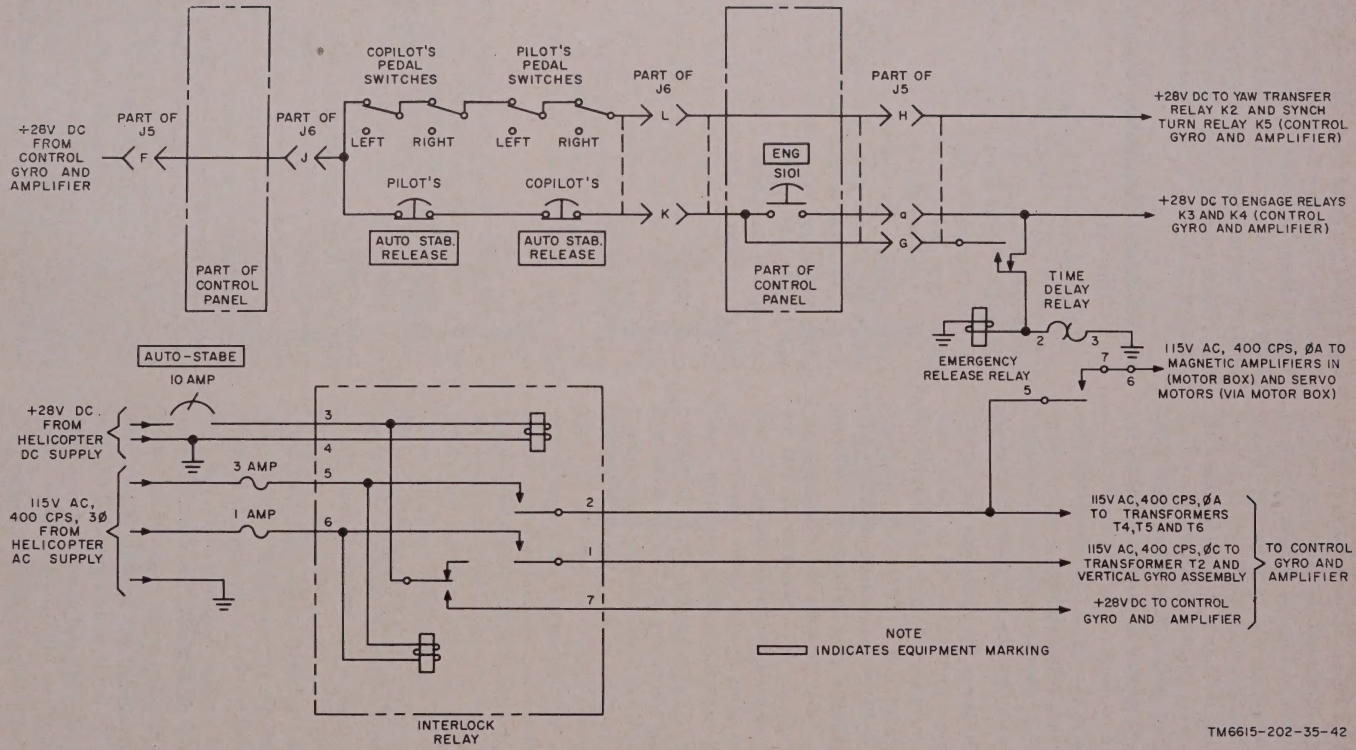


Figure 24. Flight control switches and external relays, schematic diagram.

trol gyro and amplifier, through the normally closed contacts of STANDBY switch S105 and pin R of connector J5 in the control panel. Closing ENG switch S101 applies +28 volts dc to the coil of the emergency release relay and to the heater coil of the time delay relay through pin *a* of connector J5 and the closed contacts of the emergency release relay. The holding contact of the emergency release relay holds the relay energized relay by the +28 volts dc applied from terminal 13 of TB101 through pin G of J5. Closing ENG switch S101 also applies +28 volts dc through pin *a* of connector J5 (control panel) and pin Q of connector J4 (control gyro and amplifier) to engage relays K3 and K4, energizing both relays. Yaw transfer relay K2 is energized by +28 volts dc applied through contacts 3–4 of engage relay K3, which is jumpered through pins P and N of connector J1 to yaw transfer relay K2. Closing normally open contacts 9–10 of engage relay K3 enables altitude control relay K7 to be energized when BAR ALT switch S102 is depressed. Closing BAR ALT switch S102 applies +20 volts dc to altitude control relay K7 through pin T of connector J5 (control panel) and pin T of connector J4 (control gyro and amplifier) to altitude control relay K7. This voltage is also applied to the clutch coil of the altitude control through pin P of connector J3 (control gyro and amplifier) to pin E of connector J9 (altitude control).

27. AC Power Distribution Circuits
(fig. 79)

a. The required 115-volt, 400-cps, 3-phase power is supplied to the autopilot by either a main or a spare inverter, both of which are part of the helicopter power equipment. The output of either inverter is selected at the pilot's option. Time delay provisions are included to allow electron tube filaments to heat and to allow the vertical gyro in the control gyro and amplifier to come up to speed before application of ac power to the magnetic amplifiers in the motor box. The power from the helicopter 115-volt AC bus is applied to normally open contacts of the AC-DC interlock relay through a 3-ampere fuse in the phase A line, and a 1-ampere fuse in the phase C line. The phase B line is grounded. The ac contacts on the interlock relay are controlled by a DC operated relay and are closed when the 10-ampere AUTO STABE circuit breaker is closed. With the ac contacts closed, AC power is applied to pins S and U of connector J2 on the control gyro and amplifier. This three-phase power is applied through the control gyro and amplifier directly to the vertical gyro assembly through resistors R31, R32 and R30 to pins 1, 2, and 3 of connector J5. The vertical gyro is the only system requiring three-phase power.

b. Phase A of the 115-input is applied through the control gyro and amplifier to the rotors of pitch synchro B113, roll synchro B121, and to snubber L131 through connector J5. The phase B line or ground is the common AC return. Phase A reference voltage is also distributed through pin 1 of connectors J19, J13, J17, and J11 in the control gyro and amplifier to the servo amplifiers for the pitch, altitude, roll, and yaw modes, respectively.

c. Within the control gyro and amplifier, phase A of the 115-volt input is applied to the primary windings of power transformers T4, T5, and T6. One tap on the primary of transformer T4 supplies 20 volts ac through pin 7 of connector J23 to energize the main field winding of the generator of the yaw synchronizer assembly, and through a phase-shifting network consisting of capacitor C14 and resistor R28 and pin 4 of connector J23 to the main field of the motor of the yaw synchronizer assembly. This 20 volts ac is also applied to the multiple-channel amplifier through pin 2 of connector J15. The second tap on the primary winding of transformer T4 supplies 30 volts ac for NULL IND. CENT. potentiometer R602 through pin 8 of connector J21, and for the altitude control through pin M of connector J3 on the control gyro and amplifier. The secondary winding on transformer T4 supplies 1 volt ac through pin A of connector J4 on the control gyro and amplifier and pin A of connector J5 on the control panel to energize the stator of C G TRIM control B102. This 1-volt ac voltage is also applied through pin A of connectors J6 and J7 to the stator of the roll canceller and through pin E of J6 and B of J7 to the stator of the pitch canceller. The output of rectifier V1 supplies +275 volts and +150 volts dc operating voltages. Transformer T6 secondary supplies 60 volts and 15.5 volts ac to the pitch and roll torquers in the vertical gyro assembly. Secondary winding 3–4 supplies filament voltage for rectifier V1.

d. AC voltage to the motor box is applied through contacts 5–7 of the time delay relay. The purpose of this relay is to allow a 2-second time delay after disengagement of the autopilot, thus allowing the servo motors to null, preventing a hard-over condition upon re-engagement of the autopilot. Phase A

of the 115-volt ac input is applied directly from the AC-DC interlock relay to terminal 5 of the time delay relay. After autopilot engagement, the time delay relay closes to connect ac power from terminal 6 to pin B of connector J19 on the motor box. This ac power is applied to the excitation windings of the magnetic amplifiers, the tachometer generator potentiometers, and to the primary of transducer transformer T101. The secondary of T101 supplies a stepped-down energizing voltage to the F. U. NULL potentiometers and through terminals H and K of connectors J16, J17, J15, and J14 to the pitch, altitude, roll, and yaw transducers. The common return for all AC circuits is phase B ground.

Section VII. MECHANICAL CONTROL LINKAGE SYSTEMS

28. Main Rotor Flight Control Linkage

(fig. 25)

a. The main rotor flight control linkage of Helicopter H–34A consists of three similar linkage systems. Two of these linkage systems transmit pilot-applied loads from the cyclic control stick to the main rotor mixing unit, controlling pitch and roll. The third linkage system transmits pilot-applied loads from the collective pitch stick to the main rotor mixing unit, controlling altitude. Each linkage system includes a primary servo which reacts to pilot-applied loads, and an auxiliary servo which reacts to autopilot signals and also to pilot-applied loads in case of a primary failure.

b. Operation of the main rotor flight control linkage and the related servos can be best understood by referring to figure 25 and considering the normal primary servo response to a pilot-applied load. Figure 25 illustrates the main rotor linkage system for collective pitch control with the related autopilot servo motor, tachometer generator, transducer, motor box magnetic amplifier, and control gyro servo amplifier.

(1) The pilot's input is applied at the cyclic control stick at point A, causing member AC to pivot about point C.

(2) Point B is moved a distance proportional to the displacement of A, moving point D and causing member EF to pivot about fixed point G, thereby compressing the collective open loop spring cylinder.

(3) Point E is moved, moving point H and causing member HI to pivot about point I. (Assuming the autopilot is not engaged, point I is fixed.)

(4) Point J is moved, actuating the pilot valve, which directs hydraulic flow into the power piston.

(5) The power piston shifts, moving points C and, through the mixing unit and the rotor head linkage changes the angle of attack of the main rotor blades.

(6) As point C moves, member AC pivots about point A (assuming that the pilot has stopped moving the cyclic control stick), moving point B a distance proportional to the displacement of point C.

(7) As point B moves, points D, F, E, H, and J move in a direction opposite to their initial movements described in (2), (3), and (4) above.

(8) As point J moves, the pilot valve closes and the power piston stops shifting. Since the motion of point C feeds back to stop the power piston when it has compensated for the pilot-applied displacement of point A, an output from the mixing unit proportional to the input is obtained.

c. The main rotor flight control linkage systems for roll and pitch are the same as the collective pitch linkage system, except that they do not have an open loop spring cylinder.

d. When the autopilot is engaged, the sensing system applies a voltage through the servo amplifier and the magnetic amplifier to the servo motor. Mounted on the threaded servo motor shaft is a nut and trunnion assembly which moves in the manner of a jackscrew as the shaft rotates. As the motor rotates, the tachometer generator develops a voltage which serves to dampen the motor rotation. The displacement of the trunnion assembly develops a proportional voltage in the displacement transducer which is mixed with the tachometer generator output and returned to the amplifier, tending to cancel the input from the sensing units. Motor response to the input voltage is limited by the position of the trunnion assembly, thereby insuring that

motor response to the input voltage is smooth and precise.

e. The trunnion assembly is connected by a yoke at point I to differential link H–I. Since point H is fixed with respect to trunnion motion (assuming the pilot is not moving the cyclic control stick), any motion of the trunnion causes link H–I to pivot about point H, transmitting motion through point J to the pilot valve. The pilot valve moves, directing hydraulic pressure to the power piston which moves point C and, through the mixing unit and the rotor head linkage changes the angle of attack of the main rotor blades. Since the servo motor operates the small pilot valve directly, it has a very small power requirement. Movement of point C causes a feed-back motion through the linkage system to point J as described in *b*(6) through (8) above, stopping the power piston. During normal operation, autopilot input motions are small and, since point A is fixed, there is no feed-back motion at the collective pitch control stick; in such a condition, the autopilot is said to be in *closed loop.* However, when autopilot inputs are large, the collective open loop spring cylinder retards the motion of member E–F about point G. Consequently, point B becomes a fixed pivot point for member A–C, and any further motion of the power piston causes movement of the collective pitch control stick. In such a condition, the autopilot is said to be in *open loop,* with feed-back motion introduced at the collective pitch control stick. In open loop, the authority of the altitude mode is increased beyond the normal 20 per cent. The pilot may override the feed-back motion introduced by the open lop condition by overcoming the force of the collective open loop spring cylinder, thereby maintaining the limited authority concept.

f. Members H–I and A–C are, in effect, differential links which provide a means of mixing pilot inputs with autopilot inputs. These two inputs mix in any combination to produce an output motion which is transmitted to the power piston. The control stops are contained in the power piston, rather than on the pilot's stick, so that the pilot always has complete freedom to move the stick regardless of the position of the autopilot trunnion.

g. If hydraulic pressure fails, the slop eliminator allows the pilot to control the helicopter without interference from the power piston. When pressure fails, the compressed spring in the slop eliminator actuator expands and moves the piston, causing the slop eliminator to rotate about point K so as to anchor point D and open the power piston bypass. Point B is then fixed, and pilot-applied movements at point A are directly transmitted to point C, actuating the rotor head linkage through the mixing unit. The remainder of the linkage system is then inoperative, and the power piston moves freely.

29. Tail Rotor Flight Control Linkage
(fig. 26)

a. The tail rotor flight control linkage system of Helicopter H–34A controls yaw by varying the pitch of the tail rotor blades through a mechanical system of cables, pulleys, and rods. It reacts directly to pilot-applied loads and also reacts to autopilot signals through a servo unit. The tail rotor flight control linkage system is similar to the main rotor flight control linkage system except for certain design differences which are shown in figure 26.

b. The pilot's tail rotor control pedals are connected to the tail rotor linkage by cables A and B. The pilot's input motion at the pedals causes cables A and B to move. This input is restrained by a damper which prevents suddent surges of power that might overload the tail cone. Cable B wraps around pulley E and one of the two concentric pulleys at D, and connects to the tail rotor linkage. Cable A wraps around pulley C and around the other pulley at D, and connects to the power piston. With the tail rotor control pedals in a neutral position, the pilot valve is closed and the power piston is stationary. Since cable A is attached to the fixed power piston, the movement of the tail rotor control pedals causes member C–E, on which the four pulleys are mounted, to pivot about point D, compressing the yaw open loop spring and moving point F. As point F moves, differential link F–H pivots about point H, opening the pilot valve. High pressure hydraulic fluid flows through the pilot valve and actuates the power piston. As the power piston moves, attached cable A and cable B also move, actuating the tail rotor linkages; this motion also allows member C–E to return to its original position. As member C–E returns to its original position, differential link F–H closes the pilot valve, stopping the power piston.

c. When the autopilot is engaged, the sensing system applies a voltage through the servo amplifier and the magnetic amplifier to the servo motor which controls the motion of a trunnion assembly in the manner described in paragraph 28*d.* As the trunnion moves, point F is fixed (assuming that the pilot has stopped moving the tail rotor control pedals)

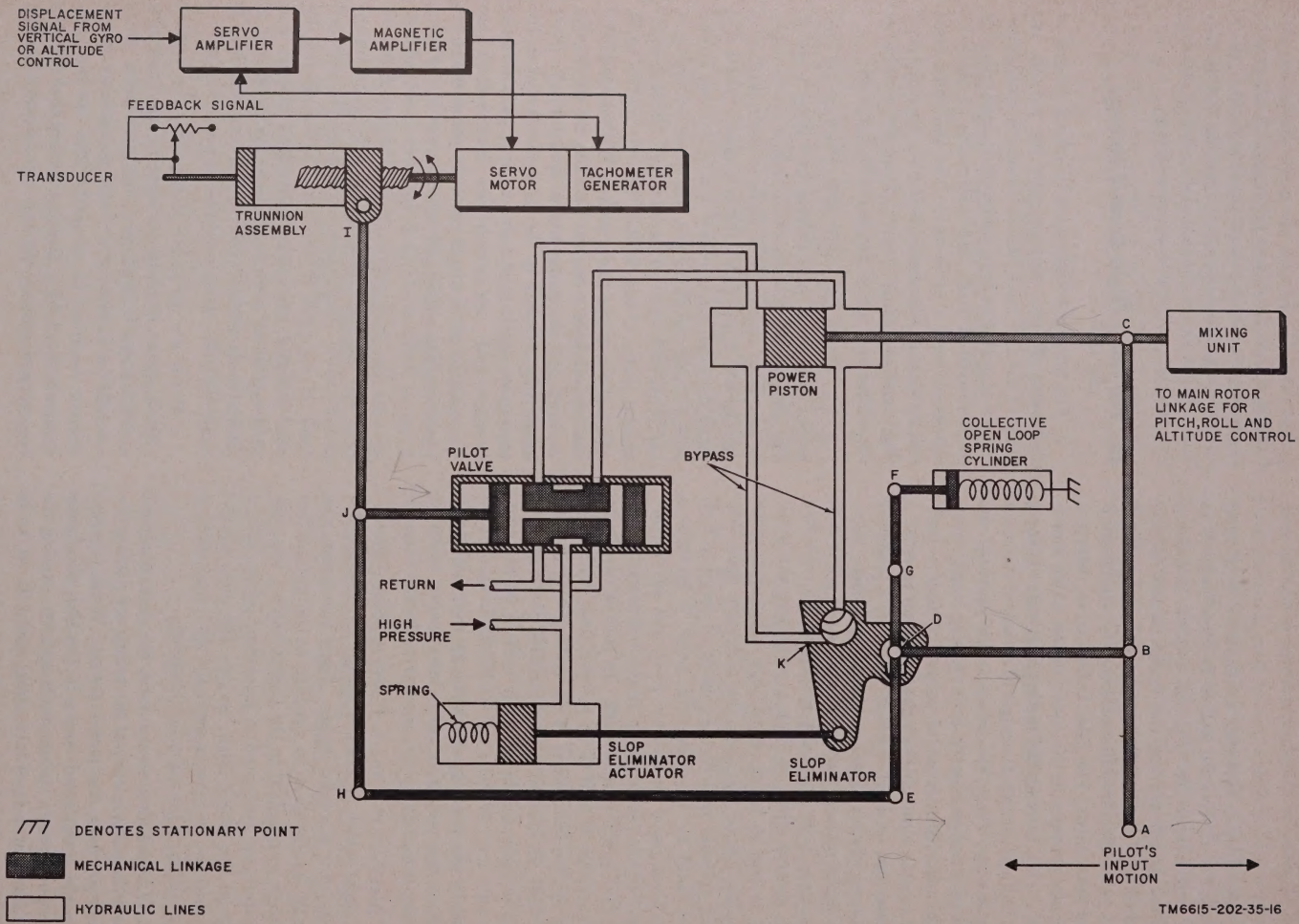


Figure 25. Main rotor collective pitch control linkage system.

and differential link F–H pivots about point F, opening the pilot valve and actuating the power piston. The power piston moves the control cables, actuating the tail rotor linkage, and member C–E returns to its original position, closing the pilot valve and stopping the power piston. During normal operation, there is no feed-back motion at the pilot's pedals, since autopilot input motions are small; in such a condition, the system is said to be in *closed loop.* However, when autopilot input motions are large, yaw open loop spring cylinder J retards the rotation of member C–E about point D. Consequently, member C–E does not fully compensate for the displacement of differential link F–H, and any additional motion of the power piston causes cables A and B to move, moving the pilot's pedals. In such a condition, the system is said to be in *open loop,* with feed-back motion being introduced at the pilot's tail rotor control pedals. In *open loop,* authority of the yaw mode increases beyond the normal 20 per cent. The pilot may override tail rotor pedal motion introduced by the open loop condition by merely overcoming the force of the pedal damper and the yaw open loop spring cylinder, thereby maintaining the limited authority concept.

d. In the event of hydraulic pressure failure, the slop eliminator actuator spring expands, causing the slop eliminator to rotate so that member C–E is locked in a fixed position and the bypass is opened, allowing the power piston to move freely. The pilot may then control the tail rotor linkage directly by means of cable motion, without interference from the inoperative linkage system.

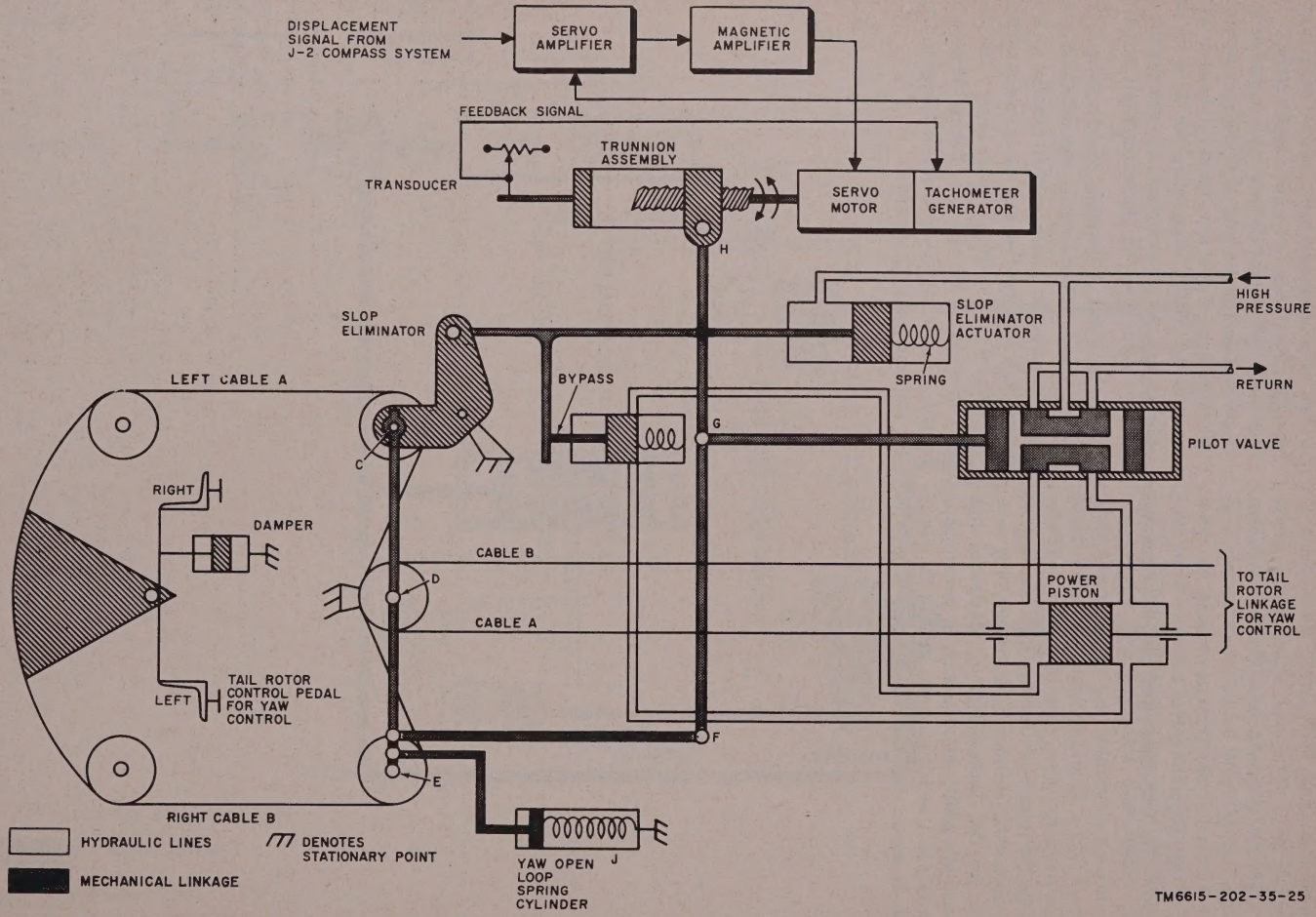


Figure 26. Tail rotor collective pitch control linkage system.

CHAPTER 2

TROUBLESHOOTING

Section I. GENERAL

Warning: **Use extreme caution when troubleshooting or performing repairs in the autopilot. Voltages as high as 300 volts are present and hazardous enough to cause personal injury. Always remove the power source from the control gyro and amplifier assembly before touching any of the internal parts. Although lower voltages exist in other components of the autopilot, be very cautious while troubleshooting these units.**

30. Scope of Field Maintenance and General Instructions

a. Troubleshooting at field and depot maintenance level includes all the techniques outlined for organizational maintenance and any special or additional techniques required to isolate a defective part. The field and depot maintenance procedures are not complete in themselves but are intended to supplement the procedures described in organizational maintenance.

Note. In addition to the maintenance checks described in TM 11–6615–202–12, periodic and special maintenance inspections for the autopilot system are listed in paragraph 34*b*.

b. Troubleshooting may be performed while the components are operating as part of a system or, if necessary, after a component (or parts of it) has been removed from service. When trouble occurs, certain observations and measurements can be made to localize a malfunction to a component. These procedures are outlined in the system troubleshooting charts (par. 35). When a malfunction has been localized to a component, further localizing to a defective part in a component can be performed by using the dc resistance and continuity measurements chart (par. 36) pertinent to that component.

c. The techniques described in the following paragraphs serve only as a partial aid in the process of troubleshooting. In conjunction with these techniques, the technician should use all other troubleshooting procedures outlined in the system troubleshooting charts including use of schematic diagrams.

31. Troubleshooting Procedure

a. General. Sectionalization is the first step in locating a defective part in the autopilot and consists of tracing a fault to a component or circuit responsible for abnormal operation. *Localization* is the second step and consists of tracing a fault to a malfunctioning subchassis or stage. *Isolation* is the third step and consists of tracing a fault to a defective part. Certain defects can often be isolated by sight, smell, or hearing; for example, charred resistors, arcing or shorted transformers, and chattering relays. In many cases, however, the fault must be localized by performing voltage and resistance measurements.

b. Sectionalization Check. When a malfunction has been sectionalized to one of the major system components, replace the defective component with one that is known to be in good condition.

c. Localization. After a malfunction has been sectionalized to a major component, a defect is then localized to a stage or subchassis in the defective unit. Localize a defect to a servo motor, magnetic amplifier, or associated parts in components not using tubes or subchassis such as the control panel, motor box, and servo motors. Check for faulty tubes, defective relays, or malfunctioning vertical gyro in the control gyro and amplifier assembly. The trouble can then be isolated within a stage, subchassis, or component by performing appropriate voltage, resistance, and continuity measurements.

(1) *Tube testing.* When a trouble is sectionalized to the control gyro and amplifier as-

sembly, it may be necessary to test tubes contained in the plug-in units and on the main chassis. Use the applicable procedures ((*a*) and (*b*) below) to test the tubes.

Caution: **Never rock or rotate a tube when removing it from a socket; pull it straight out with a tube puller.**

(*a*) *Using tube tester.* Remove and test one tube at a time. Discard a tube only if its defect is obvious or if the tube tester shows it to be defective. Do not discard a tube that tests at or slightly below its minimum test limit. Replace the original tube, or install a new one if required, before testing the next one.

(*b*) *Tube substitution method.* Replace a suspected tube with a new tube. If this does not correct the trouble, remove the new tube and replace the original tube. Repeat this procedure with each suspected tube until the defective tube is located.

Note. Modulator tubes V301 and V302 in the multiple channel amplifier assembly (control gyro and amplifier) are specially selected type 6072 tubes. These tubes have been aged and exact replacements must be used.

(2) *Troubleshooting charts.* The preflight and inflight system troubleshooting charts (par. 35) will aid the technician in localizing trouble to a component.

d. Isolation.

(1) *DC resistance and continuity measurements.* Resistance and continuity measurement charts (par. 36) should be used by the technician as an aid in locating a defective part. The technician should refer to resistor and capacitor color code diagrams (figs. 63 and 64) to determine the value and tolerance of resistors and capacitors. Tube socket resistance diagrams (figs. 80–83) indicating normal readings, enable a comparison to be made of readings taken.

(2) *Intermittent troubles.* Should an intermittent condition exist, tapping or jarring the suspected component often aids in locating the defective item. Connections to the units and associated wiring should also be checked. Often cold solder joints, or loose or improper connections to the component results in intermittent operation. Component intermittency may exist only under actual enclosed condition; for example, when the control gyro and amplifier assembly cover is in place, the internal temperature is greater than with the cover removed. Under this condition, a malfunction will appear that often will remain undetected or impossible to locate because of the lower internal operating temperature. For this reason, when component operation appears to be normal with the covers removed, the technician should attempt to operate the component with the cover in place or to simulate an identical operating condition.

32. Troubleshooting Techniques

Certain troubleshooting techniques will aid the technician in sectionalizing a malfunctioning component and localizing a defective part. The preflight, inflight, and postflight checks described in TM 11–6615–202–12, Operation and Organizational Maintenance Manual, used in conjunction with the system troubleshooting charts (par. 35), will provide an indication as to the area of malfunction within the autopilot. If all electronic components are operating normally, but any one or all mode operations cannot be fulfilled, a check of the associated mechanical linkage system must be performed. Subparagraphs *a* through *c* below provide a logical sequence of troubleshooting techniques which, when used with the troubleshooting charts, will aid in troubleshooting the autopilot.

a. If power cannot be applied to the autopilot, the pertinent autopilot fuses and AUTO STABE circuit breaker should be checked for an open condition. If a fuse is blown out or the circuit breaker is tripped, an overload may exist in the autopilot. Check cabling between affected fuse or circuit breaker and autopilot for frayed insulation and/or shorted leads. Check connectors for improper placement and broken or loose pins. When it is determined that the cables are not faulty, and the connectors are good, check the autopilot components using the process of elimination.

b. If both AC fuses blow out and the dc circuit breaker trips simultaneously, it is most likely that a cable short exists. Therefore, check those items as described in *a* above. But, if only the ac fuses or dc circuit breaker trips, an overload exists in its associated circuits. If an overload exists in the

helicopter dc supply circuits, check the autopilot control panel switches and associated wiring and check receptacles for broken pins and/or shorts between pins. Although the helicopter DC supply circuits for the autopilot are controlled by the control panel, an overload need not necessarily exist in the control panel. Therefore, the control gyro and amplifier must also be checked. All the tube filaments in the control gyro and amplifier are supplied by the helicopter dc supply circuits. If a heater short develops in a tube, an overload is imposed on the helicopter dc supply circuit. Check for this type of condition by first removing the amplifier plug-in units one at a time. If a heater short exists, the short will disappear when that particular plug-in unit is removed, and the tubes can then be tested (par. 31*c*(1)). The relays in the control gyro and amplifier are also supplied by the helicopter dc supply circuits. A shorted relay coil and/or shorted diode shunting a relay coil will also cause an overload on the helicopter DC supply circuits. This type of trouble is best located by measuring the DC resistance of the associated relays and the front-to-back resistance ratios of the diodes involved.

c. Another useful technique in locating a malfunctioning component is to disconnect components and subassemblies from the autopilot one at a time. If a DC overload exists, unplug the control panel and reset the dc circuit breaker. If the circuit breaker does not trip, trouble is in the control panel. If the circuit breaker does trip, reconnect the control panel and proceed to disconnect the control gyro and amplifier, motor box, and servo motors while observing the dc circuit breaker. If a short exists in one of the components, the overload will be removed when the component is removed from the autopilot. The defect can then be localized in the component. If the AC fuse blows out because of an overload, the servo motors can be checked with the CHANNEL DISENGAGE switches on the motor box. Operating the CHANNEL DISENGAGE switches of each servo motor, one at a time, while observing the AC fuse will indicate whether a short exists in a servo motor circuit. If a servo motor is at fault, the overload in the helicopter ac supply circuits will be removed, and the fuse will not blow out once the servo motor is removed from the AC circuit by means of the respective CHANNEL DISENGAGE switch. If servo motors are not at fault, the process of elimination described for the helicopter DC supply circuits should be performed. The motor box, control gyro and amplifier, pitch and roll cancellers, and altitude control should be disconnected, one at a time, while observing the AC fuse. The process of elimination can also be used in the control gyro and amplifier. Removal of plug-in units from the control gyro and amplifier, one at a time, will often locate a malfunctioning plug-in unit. If one of the four modes is inoperative, those circuits in the system related to the defective mode can be checked by referring to the mode block and schematic diagrams.

33. Tools and Test Equipment Required for Troubleshooting

The following chart lists tools and test equipment required for troubleshooting the autopilot. The chart does not include any *special* tools, test equipment, or test fixtures.

Item	Technical manual	Common name
Electronic Multimeter TS–505/U or equal	TM11–5511	VTVM
Electron Tube Test Set TV–7/U or equal	TM11–5083	Tube tester
Electron Tube Test Set TV–2/U or equal	TM11–2661	Tube tester
Multimeter AN/URM–105 or equal	TM11–6625–203–12	Multimeter
Voltmeter, Meter ME–30A/U or equal	TM11–5132	Voltmeter
Tool Equipment TE–113		Tool Equipment

Section II. SYSTEM TROUBLESHOOTING

34. General

a. Troubleshooting Figure Reference Chart. The following chart is a comprehensive list of figures pertinent to troubleshooting the autopilot.

Fig No.	Description
68	Yaw mode, schematic diagram.
69	Pitch mode, schematic diagram.
70	Roll mode, schematic diagram.
71	Altitude mode, schematic diagram.
72	Control panel assembly model No. 2560E, schematic diagram.
73	Control gyro and amplifier assembly model 1005N, schematic diagram.
16	Vertical gyro assembly, schematic diagram.
17	Yaw synchronizer assembly, schematic diagram.
74	Multiple-channel amplifier, schematic diagram.
75	Roll, pitch, or altitude servo amplifier, schematic diagram.
76	Yaw servo amplifier, schematic diagram.
18	Five-signal adjustment assembly, schematic diagram.
19	Twelve-signal adjustment assembly, schematic diagram.
77	Motor box assembly model No. S1645–61145–1, schematic diagram.
20	Servo Motor assembly model No. S1665–61755, schematic diagram.
21	Control stick canceller assembly model No. 911D, schematic diagram.
22	Altitude control assembly model No. 2203G, schematic diagram.
24	Flight control switches and external relays, schematic diagram.
78	DC power distribution, schematic diagram.
79	AC power distribution, schematic diagram.
80	Pitch, roll, or altitude servo amplifier, tube socket resistance diagram.
81	Yaw servo amplifier, tube socket resistance diagram.
82	Multiple-channel amplifier, tube socket resistance diagram.
83	Control gyro and amplifier, main chassis assembly tube socket resistance diagram.
28	Control panel assembly model No. 2560E, bottom view.
27	Control panel assembly, model No. 2560E, top view.
29	Control gyro and amplifier assembly model No 1005N, top view, cover removed.
30	Control gyro and amplifier assembly model No. 1005N, bottom view, cover removed.
31	Control gyro and amplifier assembly model No. 1005N, rear view, cover removed.
32	Control gyro and amplifier assembly model No. 1005N, right side view, cover removed.
33	Control gyro and amplifier assembly model No. 1005N, left side view, cover removed.
34	Control gyro and amplifier assembly model No. 1005N, terminal boards TB1, TB2, and TB4, location of parts.
35	Five-signal adjustment assembly, rear view.
36	Twelve-signal adjustment assembly, rear view.
37	Pitch, roll, or altitude servo amplifier, rear view.
38	Yaw servo amplifier, rear view.
39	Multiple-channel amplifier, rear view.
40	Motor box assembly model No. S1645–61145–1 resistors and capacitors, rear view, cover removed.
41	Motor box assembly model No. S1645-61145-1 terminal boards, connectors, and magnetic amplifiers, rear view, cover removed.
84	Automatic Pilot AN/ASN–23, system connection diagram.

b. Autopilot System Checks and Adjustments Chart. The following chart lists the checks and adjustments which should be performed after completion of system troubleshooting. These checks and adjustments should also be performed whenever regular periodic ((1) below) and special ((2) below) maintenance inspections are made on the aircraft.

(1) *Periodic inspections.* Items 1 through 14 and item 19 of the following chart should be performed at intervals consistent with the regular aircraft periodic inspections.

(2) *Special inspections.* All of the items listed in the following chart should be performed at intervals consistent with the regular aircraft special inspections.

b. Autopilot System Checks and Adjustments Chart—Continued

Item	Autopilot system checks and adjustments	Component repaired or replaced	Servo motor	Motor box	Control panel	Control gyro and amplifier	Canceller (pitch or roll)	Altitude control	Tail rotor servo assembly	Auxiliary servo assembly	Tail rotor pedal damper spring	Gyro compass system component	Helicopter flight control system component	Emergency release relay or servo motor time delay relay
1	NULL INDIC meter centering and sensitivity adjustment (par. 53*a* (1) and (2)).		X			X			X	X				
2	Servo motor phasing and damping check (par. 57*a*)		X	X	X	X			X	X				
3	Servo motor bind adjustment (par. 57*b*)		X						X	X				
4	Servo motor dead band check (par. 57*c*)		X						X	X				
5	Mode engagement check (par. 58)			X	X	X								X
6	Altitude engage error check (par. 59*a*)					X		X						
7	Yaw engage error check (par. 59*b*)					X						X		
8	Roll canceller null adjustment (par. 56*a*)					X	X							
9	Pitch canceller null adjustment (par. 56*b*)					X	X							
10	Pitch mode input response check* (par. 60*a*)		X	X	X	X	X			X				
11	Roll mode input response check* (par. 60*b*)		X	X		X	X			X				
12	Yaw mode input response check (par. 60*c*)		X	X	X	X			X			X		
13	Altitude mode input response check (par. 60*d*)		X	X		X		X		X				
14	Intermode reaction checks (par. 61)					X								
15	Proportional band check (par. 62*a*)		X						X		X			
16	Yaw open loop tail rotor pedal rate check (par. 62*b*)		X						X		X			
17	Tail rotor pedal damper spring check (par. 62*c*)								X		X			
18	Tail rotor pedal override force check (par. 62*d*)		X						X		X			
19	Autopilot override check (TM 11–6615–202–12)		X						X	X	X		X	
20	Helicopter in-flight checks (TM 11–6615–202–12)		X				X	X	X	X		X	X	

* The gyro input response portion of the pitch (item 10) and roll (item 11) input response checks need *not* be performed during *periodic* maintenance inspections.

35. System Troubleshooting Charts

The following preflight and inflight troubleshooting charts (*a* and *b* below) are to be used when performing system troubleshooting on the autopilot.

a. Preflight System Troubleshooting Chart.

Item	Symptom	Probable trouble	Corrective action
1	NULL INDIC meter needle moves off-center when CHANNEL SELECTOR switch is placed to ALT., ROLL, YAW, or PITCH position.	The channel displacing the NULL INDIC meter needle requires null adjustment.	With CHANNEL SELECTOR switch in affected mode, perform appropriate null adjustment (par. 54).
2	Roll channel cannot be nulled when adjusting F. U. NULL R potentiometer.	Roll integrator null potentiometer R330 requires adjustment.	Perform roll integrator null adjustment (par. 53*e*).
		Roll integrator null potentiometer R330 defective.	Replace multiple-channel amplifier assembly (par. 47).
		Defective roll servo amplifier assembly.	Check tubes in roll servo amplifier assembly (31*c* (1)). If a tube is defective, replace it. If tubes check good, replace roll servo amplifier assembly (par. 47).
		Roll transducer defective.	Check roll transducer (par. 36*d*). If defective, replace roll servo motor assembly (par. 40).
		Defective roll servo motor assembly.	Check roll servo motor assembly for binding (par. 57*b*). Replace if defective (par. 40).

a. Preflight System Troubleshooting Chart—Continued

Item	Symptom	Probable trouble	Corrective action
3	Pitch channel cannot be nulled when adjusting F. U. NULL P potentiometer.	Defective pitch servo amplifier assembly.	Check tubes in pitch servo amplifier assembly. If a tube checks bad, replace it. If tubes check good, replace pitch servo amplifier assembly (par. 47).
		Defective F. U. NULL P potentiometer R103.	Check F. U. NULL P potentiometer (par. 37*c* (1)). Replace if defective.
		Defective pitch transducer.	Check pitch transducer (par. 37*d*). If defective, replace pitch servo motor assembly (par. 40).
		Defective pitch servo motor assembly.	Check pitch servo motor assembly (par. 57). Replace if defective (par. 40).
4	Yaw channel cannot be nulled when adjusting F. U. NULL Y potentiometer.	Yaw servo amplifier assembly defective.	Check tubes in yaw servo amplifier assembly. If a tube checks bad, replace it. If tubes check good, replace yaw servo amplifier assembly (par. 47).
		Defective F. U. NULLY Y potentiometer R101.	Check F. U. NULL Y potentiometer for open condition (par. 7*c* (1)). Replace if defective.
		Defective yaw transducer.	Check yaw transducer (par. 37*d*). Replace yaw servo motor assembly if transducer is defective (par. 40).
		Defective yaw servo motor assembly.	Check yaw servo motor assembly (par. 57). Replace if defective par. 40).
5	Altitude channel cannot be nulled when adjusting F. U. NULL A potentiometer.	Defective altitude servo amplifier.	Check tubes in altitude servo amplifier. If a tube is defective, replace it. If tubes check good, replace altitude servo amplifier assembly (par. 47).
		Defective F. U. NULL A potentiometer R104.	Check F. U. NULL A potentiometer for open condition (par. 37*c* (1)). Replace if defective.
		Defective altitude servo motor assembly.	Check altitude servo motor assembly (par. 57). Replace if defective (par. 40).
		Defective altitude transducer.	Check altitude transducer for open condition (par. 37*d*). Replace altitude servo motor assembly if transducer is defective (par. 40).
6	All channels cannot be nulled when adjusting F. U. NULL potentiometers.	NULL IND. CENT. potentiometer in 5-signal adjustment assembly requires adjustment.	Perform adjustment given in paragraph 53*a*.
		Defective NULL IND. SENS. potentiometer in 5-signal adjustment assembly.	Check NULL IND. SENS. potentiometer (par. 36*b* (2)). If control checks defective replace it.
		Defective transformer T7, crystal diode CR7, or crystal diode CR8 in control gyro and amplifier.	Check T7 (par. 36*h*), CR7, and CR8. Replace defective part (par. 52).
		Defective CHANNEL SELECTOR switch S1.	Check CHANNEL SELECTOR switch contacts for corroded or broken contacts. If defective, replace switch.

a. Preflight System Troubleshooting Chart—Continued

Item	Symptom	Probable trouble	Corrective action
7	Autopilot cannot be engaged.	Defective fuse in ac or dc distribution circuit.	Check fuse. Replace if defective.
		Defective ac-dc interlock relay on canted bulkhead.	Check continuity of ac-dc interlock relay (par. 36*g*). Replace if defective.
		Defective ENG or STANDBY switch.	Check for open contacts in switch (par. 36*a* (2)). If switch is defective, replace the control panel (par. 37).
		Defective AUTO STAB. RELEASE switch on pilot's or copilot's cyclic control stick grip or associated wiring.	Check switch and wiring continuity. If defective, notify appropriate aircraft maintenance personnel to replace switch or cyclic control stick grip.
		Defective time delay relay K9 in control gyro and amplifier.	Check heater element resistance of relay K9 (par. 36*g*). Replace if defective.
		Defective system cabling.	Perform continuity measurements of system cabling (fig. 84).
8	Autopilot cannot be engaged; ENG lamp goes on, but servo motors do not operate.	Defective tube V1, inductor L1, or transformer T5 on main chassis of control gyro and amplifier.	Check tube V1. Replace if defective. Check dc resistance of L1 and windings of T5 (par. 36*h*). Replace defective part.
9	Phase A fuse blows out continuously.	Shorted winding on turn motor or velocity generator of yaw synchronizer assembly.	Remove yaw synchronizer assembly in control gyro and amplifier. If phase A fuse does not blow out, yaw synchronizer assembly is defective. Replace the assembly (par. 48).
		Transformer in one of the servo amplifier assemblies shorted in the control gyro and amplifier.	Remove each servo amplifier one at a time. If phase A fuse does not blow out after a unit is removed, that unit is defective. Replace it (par. 47).
		Transformer T4, T5, or T6 in control gyro and amplifier shorted.	Check winding resistance of each transformer (par. 36*h*). Replace defective transformer.
		Shorted winding in one of servo motor assemblies.	Disconnect each servo motor assembly, one by one, (connectors J14, J15, J16, and J17). If fuse does not blow out after a servo motor assembly is disconnected, that unit is defective. Replace appropriate servo motor assembly (par. 40).
		Shorted winding in transformer T101 or one of the magnetic amplifiers in motor box.	Disconnect connector J19 on motor box. If fuse does not blow out, trouble is within motor box. Replace motor box (par. 39).
		Defective TACH. GEN. potentiometer.	Check each potentiometer (par. 36*c* (1)). If one potentiometer is defective, replace motor box (par. 39).
10	Phase C fuse blows out continuously.	Defective system cabling.	Check for interconductor shorts within system cabling. Repair or replace defective cable. *Note.* When checking a cable, disconnect cable from equipment. Check connectors for loose, broken, or shorted pins.

a. Preflight System Troubleshooting Chart—Continued

Item	Symptom	Probable trouble	Corrective action
		Defective vertical gyro assembly in control gyro and amplifier.	Remove vertical gyro assembly. If phase C fuse does not blow out, vertical gyro assembly is defective. Replace assembly (par. 51).
11	Autopilot remains inoperative although in an engaged condition. (Engaged condition indicated by sound of vertical gyro whine from control syro and amplifier assembly.)	Defective emergency release relay on canted bulk head.	Check emergency release relay (par. 36*g*). Replace relay if defective (par. 44).
		Defective wiring in control panel.	Check for continuity between terminals J and F of connectors J6 and J5 and between terminals K and G of connectors J6 and J5, respectively (par. 36*a*(1)). Repair defective wiring.
		Defective pilot's or co-pilot's AUTO STAB. RELEASE switch or associated wiring.	Check switch and wiring continuity. If defective, notify appropriate air craft maintenance personnel to replace switch or cyclic control stick grip.
		Defective engage relay K3 or K4 in control gyro and amplifier.	Check relay K3 and K4 (par. 36*g*). Replace control gyro and amplifier (par. 38) if a relay is defective.
12	Pilot's or copilot's AUTO STAB. RELEASE switch does not place autopliot into released condition.	Defective AUTO STAB. RELEASE switch or associated wiring.	Check switch and wiring continuity. If defective, notify apporpriate aircraft maintenance personnel to replace switch or cyclic control stick grip.
13	STANDBY switch does not return autopilot to standby condition	Defective STANDBY switch or associated wiring.	Check contacts and associated wiring of STANDBY switch (par. 36*a* (2)). Repair defective wiring. Replace switch if defective.
14	BAR ALT lamp fails to light when BAR ALT switch is depressed.	Defective BAR ALT lamp.	Replace defective lamp.
		Defective relay K7 or associated wiring in control gyro and amplifier assembly (main chassis).	Check relay K7 and associated wiring (par. 36*g*). Repair defective wiring or replace control gyro and amplifier if relay is defective (par. 38).
		Defective BAR ALT switch or associated wiring.	Check contacts and associated wiring of BAR ALT switch (par 36*a*(2)). Repair defective wiring. Replace switch if defective.
15	BAR ALT OFF switch will not disengage altitude mode. (As indicated by failure of BAR ALT lamp to go out.)	Defective BAR ALT OFF switch or associated wiring.	Check contacts and associated wiring of BAR ALT OFF switch (par. 36*a* (2)). Repair defective wiring. Replace switch if defective.
		Defective relay KT in control gyro and amplifier (main chassis).	Check relay K7 (par. 36*g*) and associated wiring. Replace control gyro and amplifier if relay is defective (par. 38).
		Defective crystal diode CR12 in control gyro and amplifier (main chassis).	Replace CR12 if defective.

a. Preflight System Troubleshooting Chart—Continued

Item	Symptom	Probable trouble	Corrective action
16	Altitude mode inoperative. (As determined by altitude mode input response test (par. 59*d*).	Static port or altitude control clogged.	Clean moisture from static port line.
		Defective relay K7 in control gyro and amplifier (main chassis).	Check relay K7 (par. 36*g*) and associated wiring. Replace control gyro and amplifier if realy is defective (par. 38).
		Defective wiring between altitude control and control gyro and amplifier.	Check for interconductor shorts or opens in cable between altitude control and control gyro and amplifier (fig. 84).
		Defective altitude preamplifier tube V2 on main chassis of the gyro control and amplifier, or altitude servo amplifier assembly.	Check tube V2, and tubes in altitude servo amplifier assembly. If tubes check good, replace servo amplifier assembly. If trouble persists, replace control gyro and amplifier (par. 47).
17	Helicopter jump excessive when BAR ALT switch is pressed.	Defective altitude control.	Replace altitude control (par .41).
18	YAW TRIM control rotation does not produce helicopter heading change.	Defective YAW TRIM control or associated wiring.	Check continuity of YAW TRIM control and associated wiring (par. 36*a* (4)). Replace control panel if YAW TRIM control is defective (par. 37).
19	Helicopter oscillates in yaw.	Defective transducer or tachometer generator in yaw servo motor assembly.	Replace yaw servo motor assembly (par. 40).
20	Yaw mode inoperative. (As indicated by NULL INDIC meter failing to respond to pedal movement of rotation of YAW TRIM knob.)	Defective transfer relay K2 in control gyro and amplifier (main chassis).	Check relay K2 (par. 36*g*). If relay is defective, replace control gyro and amplifier (par. 38).
		Defective yaw servo amplifier assembly.	Check tubes in yaw servo amplifier assembly. If tubes check good, replace yaw servo amplifier assembly (par. 47). If trouble persists, proceed with *c* below.
		Defective yaw synchronizer assembly on control gyro and amplifier.	Replace yaw synchronizer assembly (par. 48).
		Defective YAW TRIM control or associated wiring.	Check continuity of YAW TRIM control and associated wiring (par. 36*a* (4)). Replace control panel if control is defective (par. 37).
21	Yaw channel does not remain nulled when autopilot is in standby condition.	Defective pilot's or copilot's tail rotor pedal switch.	Check switches and associated wiring (fig. 84). Repair defective wiring or replace faulty switch.
		Defective relay K2 or K5 in control gyro and amplifier (main chassis).	Check relays (par. 36*g*). If a relay is defective, replace control gyro and amplifier (par. 38).
		Defective yaw synchronizer assembly on control gyro and amplifier.	Replace yaw synchronizer (par. 48).
22	NULL INDIC meter needle does not deflect when cyclic control stick is moved *fore* and *aft*.	Defective pitch canceller.	Check continuity of pitch canceller (par. 36*e*). Replace pitch canceller if defective (par. 42).
		Loose linkage to pitch canceller rotor.	Check for loose coupling to rotor of pitch canceller and loose adjustment ring screws. Tighten as necessary. *Note.* For adjustment and alignment of pitch canceller, refer to paragraph 56.

a. Preflight System Troubleshooting Chart—Continued

Item	Symptom	Probable trouble	Corrective action
23	NULL INDIC meter needle does not deflect when cyclic control stick is moved right and left.	Defective roll canceller.	Check continuity of roll canceller (par. 36*e*). Replace roll canceller if defective (par. 42).
		Loose linkage to roll canceller rotor.	Check for loose coupling to rotor of roll canceller and loose adjustment ring screws. Tighten as necessary. *Note.* For adjustment and alignment of roll canceller, refer to paragraph 56.
24	Pitch, roll, yaw, or altitude servo motor will not null in standby condition.	Defective servo amplifier.	Check tubes in appropriate servo amplifier assembly. If tubes check good, replace the servo amplifier assembly (par. 47).
25	NULL INDIC meter needle deflects in wrong direction for fore and aft or lateral movement of the cyclic control stick.	Phasing of pitch or roll canceller reversed.	Loosen canceller adjustment screws and rotate canceller 180°. (Red dots must line up.) *Note.* For adjustment procedure, refer to paragraph 56.
26	NULL INDIC meter needle does not deflect when C G TRIM control is rotated.	Defective C G TRIM control.	Check continuity of C G TRIM control (par. 36*a* (3)). Replace control panel if control is defective.
27	When autopilot is engaged, NULL INDIC meter needle deflects, then slowly returns to null position.	Defective transformer T6 on control gyro and amplifier (main chassis).	Check transformer T6 (par. 36*h*). Replace transformer if defective.
28	With autopilot engaged, NULL INDIC meter needle deflects slowly to one side or indicates hard-over signal.	Defective transformer T6 in control gyro and amplifier (main chassis).	Check transformer T6 (par. 36*h*). Replace transformer T6 if defective.
		Defective vertical gyro assembly on control gyro and amplifier.	Replace vertical gyro assembly (par. 51).
29	Servo motor assembly inoperative (either altitude, yaw, pitch or roll); although NULL INDIC meter needle indicates motor input signal.	Servo motor assembly binding.	Check affected servo motor assembly for binding (par. 57). Check for foreign matter in servo motor assembly; check for physical damage of servo motor assembly cover. If above checks good, and trouble persists, replace servo motor assembly (par. 40).
30	Servo motor inoperative (either pitch, roll, altitude, or yaw). NULL INDIC meter needle indicates *no* motor input signal.	Defective servo amplifier assembly.	Check tubes in servo amplifier of affected mode. If tubes check good, replace appropriate servo amplifier assembly (par. 47). If trouble persists, check for defective potentiometer in 12-signal adjustment assembly (par. 36*b* (3)). Replace potentiometer if defective.
		Defective vertical gyro assembly.	Replace vertical gyro assembly (par. 51).
		Defective altitude control (if altitude channel is affected).	Replace altitude control (par. 41).
		Defective control gyro and amplifier.	Replace control gyro and amplifier (par. 38).
31	Servo motor (either altitude, yaw, roll, or pitch) oscillates after adjustment check.	Defective tube in servo amplifier of affected mode.	Check tubes in servo amplifier assembly in affected mode. Replace defective tube.
		Defective rate circuit in affected mode servo amplifier assembly.	Replace servo amplifier assembly (par. 47).
		Defective servo motor assembly.	Check servo motor (par. 57). Replace defective servo motor assembly (par. 40).

a. Preflight System Troubleshooting Chart—Continued

Item	Symptom	Probable trouble	Corrective action
32	Interaction between pitch, roll, altitude and yaw servo motors as indicated in intermode reaction check (par. 60).	Servo motor assembly cable shields not grounded.	Check for loose or broken cable shield grounds.
		Defective wiring or part on control gyro and amplifier main chassis.	Replace control gyro and amplifier (par. 38).
33	Servo motor response sluggish (either roll, altitude, pitch, or yaw).	Defective tube in associated servo amplifier assembly on control gyro and amplifier.	Check tubes. Replace faulty tube.
		Defective servo amplifier assembly.	Replace appropriate servo amplifier assembly (par. 47).
		Defective RATE potentiometer on 12-signal adjustment assembly.	Check RATE potentiometer (par. 36*b* (3)). Replace potentiometer if defective.
34	Null indicator does not show proper travel, or shows unequal travel left and right when cyclic control stick is moved from one extreme to other for both pitch and roll channels.	Null indicator needle not properly adjusted.	Adjust null indicator needle (par. 53*a*).
		NULL IND. CENT. potentiometer defective on the 5-signal adjustment assembly.	Check NULL IND. CENT. potentiometer (par. 36*b* (2)). Replace potentiometer if defective.
		Defective crystal diode CR7 or CR8 on control gyro and amplifier main chassis.	Replace CR7 or CR8.
35	NULL INDIC needle does not indicate full left (any mode). (OVERRIDE CHECK switch in LEFT FWD. DOWN position, and CHANNEL SELECTOR switch rotated through PITCH, ROLL, and YAW positions.)	Defective OVERRIDE CHECK switch.	Check OVERRIDE CHECK switch (par. 36*c* (1)). Replace if defective.
		Defective DISPL FEEDBACK potentiometer on 12-signal adjustment assembly.	Check DISPL FEEDBACK potentiometer (par. 36*b* (3)). Replace potentiometer if defective.
36	Vertical gyro does not come up to speed (no gyro whine).	Defective vertical gyro assembly.	Replace vertical gyro assembly (par. 51).
		Defective transformer T6 on control gyro and amplifier (main chassis).	Check transformer T6 (par. 36*h*). Replace transformer if defective.
		Defective relay K6, K5, or K1 on control gyro and amplifier (main chassis).	Check relays (par. 36*g*). Replace control gyro and amplifier if relay K6, K5, or K1 is defective (par 38).
37	Tail rotor pedals do not respond when YAW TRIM control knob is rotated in either direction.	YAW TRIM control knob loose or broken.	Tighten or replace YAW TRIM control knob.
		Tail rotor pedal switch defective	Check switch and replace if defective.
		Yaw servo motor binding.	Check yaw servo motor for binding (par. 57*b*). Replace servo motor if defective (par. 40).
		Defective yaw transfer relay K2 or synch turn relay K5 on control gyro and amplifier (main chassis).	Check relays K2 and K5 (par. 36*g*). Replace control gyro and amplifier if relay is defective (par. 38).
38	Heading does not change while taxing when YAW TRIM control is rotated.	YAW TRIM control synchro defective.	Check synchro (par. 36*a*(4)). Replace control panel if synchro is defective.
		Yaw servo motor defective.	Check yaw servo motor (par. 36*d*). Replace servo motor if defective (par. 40).
		Yaw synchronizer assembly defective in control gyro and amplifier.	Replace yaw synchronizer assembly (par. 48).
		Yaw servo amplifier assembly defective in control gyro and amplifier.	Check tubes. If tubes check good, replace yaw servo amplifier assembly (par. 47).

a. Preflight System Troubleshooting Chart—Continued

Item	Symptom	Probable trouble	Corrective action
39	Servo motor (pitch, roll, altitude or yaw) returns to null when channel is engaged, but is unable to null in standby.	Defective associated servo amplifier assembly in gyro control and amplifier.	Check tubes. If tubes check good, replace associated servo amplifier (par. 47).
		Servo motor assembly binding; defective transducer.	Check servo motor assembly for binding (par. 57*b*); Check transducer (par. 36*d*). Replace servo motor assembly if defective (par. 40).
		Defective associated F.U. NULL potentiometer, magnetic amplifier, or defective transformer T101 in in motor box.	Replace motor box if potentiometer, magnetic amplifier, or transformer is defective.
		Defective DISPL. FEEDBACK potentiometer on 12-signal adjustment assembly.	Check DISPL. FEEDBACK potentiometer (par. 36*a*(3)). Replace potentiometer if defective.
		Defective tachometer generator in servo motor assembly.	Check tachometer generator (par. 36*d*). Replace servo motor assembly if tachometer generator is defective (par. 40).
40	Autopilot operative, but NULL INDIC needle does not move.	Defective NULL INDIC meter on control panel.	Replace NULL INDIC meter.
		Defective CHANNEL SELECTOR switch or MOTOR POSITION-MOTOR INPUT switch.	Check switches for broken, corroded, or loose contacts. Replace switch if defective.
		Defective NULL IND. SENS. or NULL IND. CENT. potentiometer on 5-signal adjustment assembly.	Check NULL IND. SENS. and NULL IND. CENT. potentiometer. Replace potentiometer if defective.
		Defective transformer T7 on gyro control and amplifier (main chassis).	Check transformer T7 (par. 36*h*). Replace transformer if defective.

b. Inflight System Troubleshooting Chart.

Item	Symptom	Probable trouble	Corrective action
1	ENG lamp does not light and autopilot cannot be engaged when ENG switch is depressed.	Defective fuse in ac or dc distribution circuit.	Check fuses. Replace defective fuse.
		Defective AC-DC interlock relay.	Check continuity of AC-DC interlock relay (par. 36*g*). Replace relay if defective.
		Defective ENG switch on control panel.	Check switch (par. 36*a*(2)). Replace switch if defective.
		Defective STANDBY switch on control panel.	Check switch (par. 36*a*(2)). Replace switch if defective.
		Defective relay K9 on control gyro and amplifier (main chassis).	Check relay K9 (par. 36*g*). Replace relay if defective.
		Defective AUTO STAB. RELEASE switch on cyclic control stick.	Check contacts of AUTO STAB. RELEASE switch. Replace defective switch.
2	BAR ALT. light fails to come on; autopilot does not maintain altitude of helicopter. BAR ALT. switch depressed.	Defective BAR ALT. switch on control panel.	Check switch (par. 36*a*(2)). Replace switch if defective.
		Defective BAR ALT. relay K7 on gyro control and amplifier (main chassis).	Check relay K7 (par. 36*g*). Replace control gyro and amplifier if relay is defective (par. 38).

b. Inflight System Troubleshooting Chart—Continued

Item	Symptom	Probable trouble	Corrective action
3	Helicopter heading change is not in accordance with tail rotor pedal movement when initiating a turn using the tail rotor pedals.	Defective tail rotor pedal linkage.	Refer to appropriate maintenance personnel.
		Defective tail rotor pedal switch.	Check switch. Replace switch if defective.
		Defective YAW TRIM synchro on control panel.	Check YAW TRIM synchro (par. 36*a*(4)). Replace control panel if synchro is defective (par. 37).
		Defective yaw synchro on control gyro and amplifier yaw synchronizer assembly.	Replace yaw synchronizer assembly (par. 48).
		Defective yaw transfer relay K2 on control gyro and amplifier (main chassis).	Check relay K2 (par. 36*g*). Replace control gyro and amplifier if relay K2 is defective (par. 38).
		Defective quadrature nulling circuit (T1, R2 through R5, R20 or C14 on main chassis of gyro control and amplifier or VEL. GEN. QUAD. potentiometer R603 on 5-signal adjustment assembly).	Check quadrature nulling circuit components. Replace T1, R2 through R5, R603 or C14 if defective. Replace the control gyro and amplifier if R20 is defective (par. 38).
		Defective yaw synchronizer assembly.	Replace yaw synchronizer assembly (par. 48).
		Defective turn amplifier (V303, V304, or V305) on multiple channel amplifier assembly.	Check tubes. If tubes check good, replace multiple channel amplifier (par. 47).
		Defective transformer T8 on control gyro and amplifier (main chassis).	Check transformer T8 (par 36*h*). Replace transformer if defective.
		Defective synch turn relay K5 on control gyro and amplifier (main chassis).	Check relay K5 (par. 36*g*). Replace control gyro and amplifier if relay is defective (par. 38).
4	Helicopter fails to maintain heading within ±5° transient error when an abrupt manifold pressure change is made.	Defective YAW TRIM synchro on control panel.	Check YAW TRIM synchro (par. 36*a*(4)). Replace control panel if synchro is defective (par. 37).
		Defective yaw synchro on control gyro and amplifier yaw synchronizer assembly.	Replace yaw synchronizer assembly (par. 48).
		Defective yaw servo amplifier assembly.	Check tubes. If tubes check good, replace yaw servo amplifier assembly (par. 47).
		YAW channel DISPL FEEDBACK, DISPL, or RATE potentiometer on 12-signal adjustment assembly requires adjustment or is defective.	Check for proper adjustment (par. 53*b*). Replace defective potentiometer.
		Defective yaw servo motor assembly.	Check yaw servo motor assembly (par. 36*d*). Replace yaw servo motor assembly if defective (par. 40).
5	Helicopter continues to turn for more than 30° or, does not return to the heading which existed at the instant the pilot's feet were removed from the tail rotor pedals after initiating a 15-degree-per-second turn into the wind.	Defective tail rotor pedal switch.	Check pedal switch. Replace switch if defective (par. 43).
		Defective yaw synchro on control gyro and amplifier yaw synchronizer assembly.	Replace yaw synchronizer assembly (par. 48).
		Yaw servo motor assembly binding.	Check yaw servo motor for binding (par. 57*b*). Replace servo motor assembly if defective (par. 40).

b. Inflight System Troubleshooting Chart—Continued

Item	Symptom	Probable trouble	Corrective action
		Defective quadrature nulling circuit (T1, R2 through R5, R20 or C14 on main chassis of gyro control and amplifier or VEL. GEN. QUAD. potentiometer R603 on 5-signal adjustment assembly).	Check quadrature nulling circuit components. Replace T1, R2 through R5, R603 or C14 if defective. Replace gyro control and amplifier if R20 is defective (par. 38).
6	Helicopter does not follow YAW TRIM command of autopilot when making heading changes in either direction.	Defective YAW TRIM synchro on control panel.	Check YAW TRIM synchro (par. 36*a*(4)). Replace control panel if synchro is defective (par. 37).
		Defective yaw synchro in control gyro and amplifier yaw synchronizer assembly.	Replace yaw synchronizer assembly (par. 48).
		Defective yaw servo amplifier assembly.	Check tubes. If tubes check good, replace yaw servo amplifier assembly (par. 47).
		YAW channel DISPL FEEDBACK, DISPL, or RATE potentiometer on 12-signal adjustment assembly requires adjustment or is defective.	Check for proper adjustment (par. 53*b*). Replace defective potentiometer.
		Defective yaw servo motor assembly.	Check yaw servo motor (par. 36*d*). Replace yaw servo motor assembly, if defective (par. 40).
7	BAR-ALT. light fails to go out and altitude channel does not disengage. When BAR ALT.-OFF switch is depressed.	Defective BAR ALT. OFF switch on control panel.	Check switch (par. 36*a*(2)). Replace switch if defective.
8	When making jump take off with feet off tail rotor pedals, helicopter heading goes beyond 40° transient error.	Defective tail rotor pedal switch.	Check switch. Replace defective switch.
		Same as items 4*a* through *e* above.	Same as items 4*a* through e above.
9	Undersirable yaw oscillation develops when making transition to forward flight at cruise altitude, without using tail rotor pedals.	Yaw servo motor assembly not nulled.	Perform F. U. NULL and TACH. GEN. adjustments in motor box (par. 54).
		Defective yaw servo motor assembly.	Check yaw servo motor assembly (par. 36*d*). Replace defective yaw servo motor assembly (par. 40).
		Same as items 6*a* through *d* above.	Same as items 6*a* through *d* above.
10	Helicopter fails to maintain altitude within 40 feet. (BAR ALT switch depressed, vertical speed of helicopter zero, hands off controls.)	Static port line of altitude control clogged.	Remove moisture from static port line.
		Defective BAR ALT. relay K7 on control gyro and amplifier (main chassis).	Check relay K7 (par. 36*g*). Replace control gyro and amplifier if relay K7 is defective (par. 38).
		Defective wiring between altitude control and control gyro and amplifier.	Check aircraft wiring. Repair or replace defective wiring.
		Defective altitude preamplifier V2 (on main chassis of control gyro and amplifier) or altitude servo amplifier assembly.	Check tube V2, and tubes in servo amplifier assembly. If tubes check good, replace servo amplifier assembly (par. 47). If trouble persists, replace control gyro and amplifier (par. 38).
		Defective altitude control.	Replace altitude control (par. 41).
11	Autopilot fails to hold helicopter pitch altitude within ±1° on a smooth day.	Defective vertical gyro assembly on control gyro and amplifier.	Replace vertical gyro assembly (par. 51).
		Defective pitch bridge resistors R33 through R37 on control gyro and amplifier (main chassis).	Check resistance of pitch bridge circuit (par. 36*b* (1)). Replace defective pitch bridge resistor.

b. Inflight System Troubleshooting Chart—Continued

Item	Symptom	Probable trouble	Corrective action
		Defective pitch servo amplifier assembly.	Check tubes. If tubes check good, replace servo amplifier assembly (par. 47).
		Pitch servo motor assembly defective.	Check pitch servo motor assembly (par. 36*d*). If defective, replace pitch servo motor assembly (par. 40).
12	Autopilot fails to hold helicopter roll altitude within ±1° on a smooth day.	Defective vertical gyro assembly on control gyro and amplifier.	Replace vertical gyro assembly (par. 51).
		Defective roll bridge resistors R40 through R44.	Check resistance of roll bridge circuit (par. 36*b* (1)). Replace defective roll bridge resistor.
		Defective roll servo amplifier assembly.	Check tubes. If tubes check good, replace servo amplifier assembly (par. 47).
		Defective roll servo motor assembly.	Check roll servo motor (par. 36*d*). If defective, replace roll servo motor assembly (par. 40).
13	ENG light fails to go out, and autopilot does not disengage. (STANDBY switch depressed).	Shorted STANDBY or ENG switch.	Check each switch (par. 36*a* (2)). Replace switch if defective.
14	Autopilot disengages, but there is apparent helicopter jump. (STANDBY switch depressed).	Defective servo motor assembly.	Check servo motor assemblies for binding (par. 57*b*) and nulling (par. 54). Replace appropriate servo motor assembly if defective (par. 40).
15	Helicopter oscillation exceeds ±5° in roll when using tail rotor pedals to make a 25° banked turn. (Cyclic control stick centered.)	Defective tail rotor pedal switch.	Check pedal switches. Replace defective switch (par. 43).
		Defective synch turn relay K5 on control gyro and amplifier (main chassis).	Check relay K5 (par. 36*g*). Replace control gyro and amplifier if relay is defective (par. 38).
		Defective vertical gyro assembly in control gyro and amplifier.	Replace vertical gyro assembly (par 51).
		Defective transducer on roll servo motor assembly.	Check transducer (par. 36*d*). Replace roll servo motor assembly if transducer is defective (par. 40).
16	Helicopter oscillator exceeds ±5° in pitch when using tail rotor pedals to make a 25° banked turn. (Cyclic control stick centered.)	Defective vertical gyro assembly in control gyro and amplifier.	Replace vertical gyro assembly (par. 51).
		Defective transducer on pitch servo motor assembly.	Check transducer (par. 36*d*). Replace pitch servo motor assembly if transducer is defective (par. 40).
17	Autopilot fails to hold helicopter stable in yaw. Hands and feet removed from controls.	Defective YAW TRIM synchro on control panel.	Check YAW TRIM synchro (par. 36*a* (4)). Replace control panel if synchro is defective (par. 37).
		Defective yaw synchro on control gyro and amplifier yaw synchronizer assembly.	Replace yaw synchronizer assembly (par. 48).
		Defective yaw transfer relay K2 on control gyro and amplifier (main chassis).	Check relay K2 (par. 36*g*). Replace control gyro and amplifier if relay K2 is defective (par. 38).
		Defective yaw servo amplifier assembly.	Check tubes. If tubes check good, replace yaw servo amplifier assembly (par. 47).
		Defective yaw servo motor assembly.	Check servo motor assembly (par. 36*d*). Replace defective yaw servo motor assembly (par. 40).

36. DC Resistance and Continuity Measurements

The following charts contain DC resistance measurements for each major component in the autopilot system (*a* through *f* below) as well as resistance and continuity measurements for all relays (*g* below) and transformers and coils (*h* below). The resistance measurements for each major component must be taken with the component removed from the autopilot system. When taking measurements on the control gyro and amplifier main chassis, all plug-in units must be removed or disconnected from the main chassis. Use the following charts in conjunction with the appropriate component schematic diagram.

a. Control Panel (fig. 72).

(1) *Chassis resistance and continuity measurements.*

Point of measurement		Resistance (ohms)
From connector	To connector	
J5–A	J6–A	0
J5–A	J6–E	0
J5–A	J5–D	4
J5–C	J6–C	0
J5–D	J6–B	0
J5–D	J6–F	0
J5–E	J6–G	240
J5–E	J6–H	750
J5–E	J5–c	1050
J5–F	J6–J	0
J5–G	J6–K	0
J5–G	J5–R	0
J5–H	J6–L	0
J5–J	J6–M	0
J5–K	J5–L	14
J5–K	J5–M	14
J5–L	J5–M	14
J5–S	J5–Z	0
J5–S	J5–U	0
J5–V	J6–S	0
J5–B	J6–D	0
J6–N	J6–P	10.8
J6–N	J6–R	10.8
J6–P	J6–R	10.8
J5–U	J5–X	0

(2) *Switch continuity measurements.*

Switch	Switch position	Point of measurement		Resistance (ohms)
		From connector	To connector	
ENG (S101)	Released	J5–G	J5–a	Inf
ENG (S101)	Depressed	J5–G	J5–a	0
BAR ALT (S102)	Released	J5–S	J5–T	Inf
BAR ALT (S102)	Depressed	J5–S	J5–T	0
STANDBY (S105)	Released	J5–G	J5–R	0
STANDBY (S105)	Depressed	J5–G	J5–R	Inf
OFF (S106)	Released	J5–S	J5–U	0
OFF (S106)	Depressed	J5–S	J5–U	Inf

(3) *C G TRIM control resistance measurements.*

Winding	Point of measurement		Resistance (ohms)
	From pin	To pin	
Stator	3	5	4
Rotor	1	4	333 to 407

(4) *YAW TRIM control resistance measurements.*

Winding	Point of measurement		Resistance (ohms)
	From lead	To lead	
Stator	Black	Yellow	10.8
Stator	Black	Blue	10.8
Stator	Blue	Yellow	10.8
Rotor	Yellow	Blue	14
Rotor	Yellow	Black	14
Rotor	Blue	Black	14

b. Control Gyro and Amplifier.

Notes.

1. Disconnect the vertical gyro assembly from the main chassis and remove all plug-in units before proceeding with the following resistance measurements.

2. All measurements specified to ground in the following chart are taken with respect to the chassis of the control gyro and amplifier.

(1) *Main chassis continuity and resistance measurements* (fig. 73).

Point of measurement		Resistance (ohms)
From	To	
J3–J	J15–3	0
J3–J	J15–8	900
J3–J	XV1–3	80
J3–J	XV1–8	80
J3–K	Ground	10K
J3–K	XV2–7	0
J3–L	Ground	0
J3–M	Ground	1.5
J3–N	Ground	0
J3–P	Ground	240
J3–R	Ground	0
J3–R	J5–14	0
J3–R	J5–15	390
J3–R	J5–16	390
J3–S	Ground	390
J3–S	J5–14	390
J3–S	J5–15	390
J3–S	J5–16	0
J3–T	Ground	390
J3–T	J5–14	390
J3–T	J5–15	0
J3–T	J5–16	390
J3–U	J5–11	0
J3–U	J5–12	390
J3–U	J5–13	390
J3–V	Ground	0
J3–V	V5–11	390
J3–V	J5–12	390
J3–V	J5–13	0
J4–A	Ground	0
J4–B	Ground	0
J4–C	J14–8	0
J4–D	Ground	0
J4–F	Ground	100
J4–F	J4–J	28
J4–H	Ground	9.5
J5–8	Ground	0
J5–21	Ground	0
J5–23	Ground	20K
J5–25	Ground	0
J6–1	J10–3	0
J6–3	J10–7	0
J6–4	J10–8	0
J6–8	J11–2	0
J7–3	J16–7	0
J7–4	J16–8	0
J7–5	Ground	0
J7–8	J17–2	0
J8–1	J18–3	0
J8–3	J18–7	0
J8–5	Ground	0
J8–8	J19–2	0
J9–1	J12–3	0
J9–3	J12–7	0
J9–4	J12–8	0
J9–5	Ground	0
J9–8	J13–2	0
J10–4	Ground	0
J10–6	J15–7	0
J11–3	Ground	41K
J11–6	Ground	0
J11–9	J16–9	0
J12–4	Ground	0
J12–9	Ground	0
J13–6	Ground	0
J14–1	Ground	0
J16–4	Ground	0
J16–9	Ground	0
J2–S	Ground	3
J2–T	Ground	0
J2–U	J5–1	9
J3–A	J11–7	0
J3–B	J11–8	0
J3–C	J17–7	0
J3–D	J17–8	0

(1) *Main chassis continuity and resistance measurements* (fig. 73)—Continued

Point of measurement		Resistance (ohms)
From	To	
J4–K	J22–1	0
J4–L	J22–2	0
J4–M	J22–3	0
J4–N	J21–2	0
J4–P	Ground	700
J4–P	J21–7	2.3K
J4–Q	Ground	75
J4–T	Ground	260
J4–V	Ground	0
J1–A	Ground	300
J1–A	J4–Q	390
J1–B	Ground	300
J1–D	Ground	195 to 260
J1–D	J14–7	0
J1–E	J7–2	0
J1–F	Ground	30
J1–F	J1–X	0
J1–F	J23–2	0
J1–G	J2–G	0
J1–H	Ground	185 to 260
J1–J	J4–X	0
J1–J	J8–2	0
J1–M	Ground	0
J1–N	Ground	120 to 180
J1–N	J1–P	0
J1–N	J10–9	145
J1–Q	Ground	180
J1–Q	J2–V	0
J1–Q	J4–J	0
J1–Q	J11–9	0
J1–Q	J13–9	0
J1–Q	J15–9	0
J1–Q	J17–9	0
J1–Q	J18–9	0
J1–R	J4–U	0
J1–S	Ground	120 to 150
J1–S	J3–P	0
J1–S	J4–T	101
J1–T	Ground	0
J1–U	J4–Z	0
J1–V	Ground	4
J1–V	J2–S	0
J1–V	J5–4	0
J1–V	J5–7	0
J1–V	J5–10	0
J1–V	J5–24	0
J1–V	J11–1	0
J1–V	J13–1	0
J1–V	J17–1	0
J1–V	J19–1	0
J1–W	Ground	0.2
J1–W	J4–A	0
J1–X	Ground	20
J1–Y	Ground	0
J2–A	J6–2	0 to 1K
J2–B	J6–2	0
J2–C	J6–7	0
J2–E	J7–6	0
J2–F	J7–7	0
J2–H	J8–6	0
J2–H	J8–7	0
J2–K	J9–2	0
J2–L	J9–6	0
J2–M	J9–7	0
J2–N	Ground	0
J2–N	J6–5	0
J2–P	J2–R	400
J4–W	J14–2	0
J4–Y	J5–12	0
J4–Y	J5–11	400
J4–Y	J5–13	400
J22–4	Ground	0
J22–5	Ground	65K
J22–5	J10–9	65K
J22–5	J21–4	65K
J23–1	J14–6	0
J23–2	J21–5	0
J23–4	Ground	75
J23–5	Ground	0
J23–7	Ground	1.5
J23–7	J15–2	0
J5–2	Ground	9
J5–3	J5–5	29
J17–6	Ground	0
J18–4	Ground	0
J18–9	Ground	0
J19–6	Ground	0
J20–1	Ground	0
J20–4	Ground	0
J21–3	Ground	675
XV4–5	V2–6	45K
XV4–5	J11–3	500
XV4–5	J17–3	500
XV4–5	J19–3	500
XV4–5	J13–3	500

(2) *Five-signal adjustment assembly, resistance measurements* (fig. 18).

Control	Point of measurement		Resistance (ohms)
	From	To	
NULL IND. SENS.	P601–2	P601–3	80,000 to 120,000 (fully ccw)
VEL. GEN. QUAD.	P601–4	P601–6	800 to 1,200
	P601–4	P601–5	800 to 1,200 (fully cw)
NULL IND. CENT.	P601–7	P601–9	8,000 to 12,000
	P601–7	P601–8	8,000 to 12,000 (fully cw)
BAR. ALT. PRE-AMP.	P602–4	P602–5	20,000 to 30,000 (fully ccw)
ALT. RE-SET	P602–1	P602–2	20,000 to 30,000 (fully ccw)

(3) *Twelve-signal adjustment assembly resistance measurements* (fig. 19).

Control	Point of measurement		Resistance (ohms)
	From	To	
YAW DISPL	P501–1	P501–2	20,000 to 30,000 (fully ccw)
YAW RATE	P501–4	P501–8	40,000 to 60,000
	P501–4	P501–3	40,000 to 60,000 (fully ccw)
YAW DISPL FEEDBACK	P501–5	P501–6	800 to 1,000
	P501–5	P501–7	800 to 1,000 (fully ccw)
ROLL DISPL	P502–1	P502–2	20,000 to 30,000 (fully ccw)
ROLL RATE	P502–4	P502–8	20,000 to 30,000
	P502–4	P502–3	20,000 to 30,000 (fully ccw)
ROLL DISPL FEEDBACK	P502–5	P502–6	800 to 1,200
	P502–5	P502–7	800 to 1,200 (fully ccw)
PITCH DISPL	P503–1	P503–2	20,000 to 30,000 (fully ccw)
PITCH RATE	P503–4	P503–8	20,000 to 30,000
	P503–4	P503–3	20,000 to 30,000 (fully ccw)
PITCH DISPL FEEDBACK	P503–5	P503–6	800 to 1,200
	P503–5	P503–7	800 to 1,200 (fully ccw)
ALTITUDE DISPL	P504–1	P504–2	20,000 to 30,000 (fully ccw)
ALTITUDE RATE	P504–4	P504–8	20,000 to 30,000
	P504–4	P504–3	20,000 to 30,000
ALTITUDE DISPL FEEDBACK	P504–5	P504–6	800 to 1,200
	P504–5	P504–7	800 to 1,200 (fully ccw)

c. Motor Box (fig. 77).

(1) *Main chassis continuity and resistance measurements.*

Switch or control setting	Point of measurement		Resistance (ohms)
	From	To	
None	J14–A	J19–A	20
None	J14–A	J19–B	0
None	J14–B	J19–A	80
CHANNEL SELECTOR switch S1 to YAW, MOTOR POSITION-MOTOR INPUT switch S2 to MOTOR INPUT.	J14–B	J18–24	85
None	J14–C	J19–A	0
Rotate TACH. GEN. Y potentiometer through full range.	J14–D	J19–A	4 to 25K to 20
Rotate TACH. GEN. Y potentiometer through full range.	J14–D	J19–B	4 to 25K to 20
None	J14–F	J18–7	0
Rotate F. U. NULL Y potentiometer through full range	J14–H	J18–18	0 to 630 to 15
Rotate F. U. NULL Y potentiometer through full range	J14–H	J18–25	0 to 630 to 15
None	J14–H	J14–K	19
CHANNEL SELECTOR switch S1 to YAW	J14–H	J18–23	2,500
None	J14–J	J19–A	Inf
None	J14–J	J18–19	0
CHANNEL SELECTOR switch S1 to YAW	J14–J	J18–24	0
None	J14–K	J19–A	Inf
CHANNEL SELECTOR switch S1 to YAW	J14–K	J18–23	2,500
None	J14–L	J18–25	0
None	J14–L	J18–23	2,900
None	J15–A	J19–A	20
None	J15–A	J19–B	0
None	J15–B	J19–A	85
CHANNEL SELECTOR switch S1 to ROLL	J15–B	J18–24	Inf
CHANNEL SELECTOR switch S1 to ROLL; MOTOR POSITION-MOTOR INPUT switch S2 to MOTOR INPUT.	J15–B	J18–24	85
None	J15–C	J19–A	0
Rotate TACH. GEN. R potentiometer through full range	J15–D	J19–A	15 to 20K to 14
Rotate TACH. GEN. R potentiometer through full range	J15–D	J19B	15 to 20K to 14
None	J15–E	J18–6	0
None	J15–F	J18–5	0
Rotate F. U. NULL R potentiometer through full range	J15–H	J18–18	1 to 625 to 20
Rotate F. U. NULL R potentiometer through full range	J15–H	J18–25	1 to 625 to 20
None	J15–H	J15–K	20
CHANNEL SELECTOR switch S1 to ROLL	J15–H	J18–23	2,500
None	J15–J	J18–20	0
CHANNEL SELECTOR switch switch S1 to ROLL	J15–J	J18–24	0
CHANNEL SELECTOR switch S1 to ROLL	J15–K	J18–23	2,500
None	J15–L	J18–25	0
None	J16–A	J19–A	20
None	J16–A	J19–B	0
None	J16–B	J19–A	85
CHANNEL SELECTOR SWITCH S1 to PITCH; MOTOR POSITION-MOTOR INPUT switch S2 to MOTOR INPUT.	J16–B	J18–24	85
None	J16–C	J19–A	0
Rotate TACH. GEN. P potentiometer through full range	J16–D	J19–A	15 to 26K to 35
Rotate TACH. GEN. P potentiometer through full range	J16–D	J19–B	15 to 26K to 35
None	J16–E	J18–4	0
None	J16–F	J18–3	0
Rotate F. U. NULL P potentiometer through full range	J16–H	J18–18	4 to 640 to 20
Rotate F. U. NULL P potentiometer through full range	J16–H	J18–25	1 to 640 to 20
None	J16–H	J16–K	20
CHANNEL SELECTOR switch S1 to PITCH	J16–H	J18–23	2,500
None	J16–J	J18–21	0
CHANNEL SELECTOR switch S1 to PITCH	J16–J	J18–24	0

(1) *Main chassis continuity and resistance measurements*—Continued.

Switch or control setting	Point of measurement		Resistance (ohms)
	From	To	
CHANNEL SELECTOR switch S1 to PITCH	J16–K	J18–23	2,500
None	J16–L	J16–K	20
None	J16–L	J18–25	0
None	J17–A	J19–A	20
None	J17–A	J19–B	0
None	J17–B	J19–A	85
CHANNEL SELECTOR switch S1 to ALT; MOTOR POSITION-MOTOR INPUT switch S2 to MOTOR INPUT.	J17–B	J18–24	85
None	J17–C	J19–A	0
Rotate TACH. GEN. A potentiometer through full range.	J17–D	J19–A	15 to 26K to 35
Rotate TACH. GEN. A potentiometer through full range.	J17–D	J19–B	15 to 26K to 35
None	J17–E	J19–B	Inf
None	J17–F	J18–2	Inf
Rotate F. U. NULL A potentiometer through full range	J17H	J18–18	4 to 625 to 23
Rotate F. U. NULL A potentiometer through full range	J17–H	J18–25	4 to 625 to 23
None	J17–H	J17–K	20
CHANNEL SELECTOR switch S1 to ALT	J17–H	J18–24	2,500
None	J17–J	J18–22	0
CHANNEL SELECTOR switch S1 to ALT	J17–J	J18–23	0
CHANNEL SELECTOR switch S1 to ALT	J17–K	J18–24	2,500
None	J17–L	J18–25	0

(2) *Magnetic amplifiers, DC resistance measurements.*

Winding	Point of measurement		Resistance (ohms)
	From	To	
Control	Brown	Red	3,250 to 3,550
Control	Orange	Red	3,250 to 3,550
Input	Yellow	Violet	80 to 90
Output	Blue	Violet	80 to 90
	Case	All terminals	Inf

d. Servo Motor Assembly (Pitch, Roll, Altitude, or Yaw) DC Resistance Measurements (figs. 75 and 76).

Item under test	Point of measurement		Resistance (ohms)
	From	To	
Servo motor windings	1	3	155 to 195
	2	4	155 to 195
Tachometer generator windings	7	10	600 to 720
	8	9	900 to 1,100
Transducer resistance:			
Pitch	J16–H	J16–K	1,500 to 1,575
Roll	J15–H	J15–K	1,500 to 1,575
Yaw	J13–H	J13–K	1,500 to 1,575
Altitude	J17–H	J17–K	1,500 to 1,575
Insulation	Shield	All terminals	Inf

e. Control Stick Cancellers (Pitch or Roll) DC Resistance Measurements (fig. 21).

Winding	Point of measurement		Resistance (ohms)
	From	To	
Roll canceller:			
Stator	J7–A	J7–B	3.3
Rotor	J7–C	J7–D	325
Pitch canceller:			
Stator	J8–4	J8–B	2.3
Rotor	J8–C	J8–D	325

f. Altitude Control DC Resistance Measurements (fig. 22).

Item under test	Point of measurement		Resistance (ohms)
	From	To	
Transformer secondary winding	J9–A	J9–B	500 to 5,500
Transformer primaries P1 and P2	J9–C	J9–D	540 ± 200
Clutch coil and 120 ohm resistor	J9–D	J9–E	430 ± 100

g. Relay Recoil DC Resistance Measurements.

Relay	Location	Terminals		Resistance (ohms)
		From	To	
Erection delay K1	CG & A	1	2	10,000
Yaw transfer K2	CG & A	1	2	180
Engage K3	CG & A	1	2	180
Engage K4	CG & A	1	2	180
Synch turn K5	CG & A	1	2	180
Delay end K6	CG & A	1	2	300
Bar alt K7	CG & A	1	2	300
Time delay K9	CG & A	2	3	200
Left turn K10	CG & A	1	2	310
Right turn K11	CG & A	1	2	310
Time delay relay (motor release)	Aft right-hand side of canted bulkhead.	1	2	Inf
		1	3	Inf
		1	4	0
		1	5	Inf
		1	6	0
		1	7	0
		2	3	225
AC-DC interlock	Aft left-hand side of canted bulkhead.	1	6	Inf
		2	5	Inf
		3	4	300
		3	7	Inf
		5	6	70
Emergency release	Aft right-hand side of canted bulkhead.	1	8	280
		5	6	0
		5	7	Inf

(*Note.* Terminal numbers are arbitrarily assigned as read clockwise from red dot on base of relay.)

h. Transformer Winding and Inductance Coil DC Resistance Measurements.

Transformer or coil	Location	Terminals		Resistance (ohms)
		From	To	
T1	Main chassis	1	2	38
		3	4	0.15
T2	Main chassis	1	2	12.6
		3	4	74
T3	Main chassis	1	2	13
		3	4	295
T4	Main chassis	1	3	1.4
		1	4	2
		1	5	3
		6	7	0.1
		6	8	0.2
T5	Main chassis	1	2	5
		3	4	150
		3	5	320
T6	Main chassis	1	2	8
		3	4	0.9
		5	8	1.4
		5	9	5
T7	Main chassis of CG & A	5	4	375
		1	3	400
		1	2	200
		2	3	200
T8	Main chassis of CG & A	1	2	900
		3	4	30
T9	Main chassis of CG & A	1	2	200
		3	4	375
T10	Main chassis of CG & A	1	2	460
		3	4	100
		3	5	200
		6	7	110
		6	8	220
T201A	Pitch, roll, or altitude servo amplifier assembly.	3	4	790
T201B		5	6	700
T201C		7	8	900
T201C		1	2	100
T201D		9	10	810
T202	Pitch, roll, or altitude servo amplifier assembly.	1	2	240
		3	4	400
		5	6	400
T301	Multiple channel amplifier assembly (roll integrator circuit).	1	2	300
		3	4	89
		5	6	100
T302A	Multiple channel amplifier assembly (yaw synchronizer circuit).	1	2	1,200
		3	4	190
T302B	Multiple channel amplifier assembly (roll integrator circuit).	1	2	700
		3	4	450
T401A	Yaw servo amplifier assembly	3	4	790
T401B		4	6	780
T401C		1	2	100
T401C		7	8	900
T401D		9	10	890

h. Transformer Winding and Inductance Coil DC Resistance Measurements—Continued

Transformer or coil	Location	Terminals		Resistance (ohms)
		From	To	
T402	Yaw servo amplifier assembly	1	2	240
		3	4	400
		5	6	400
T101	Motor box	1	2	310
		3	4	31
		7	8	31
		9	10	31
L1 (coil)	Main chassis of CG & A	1	2	95

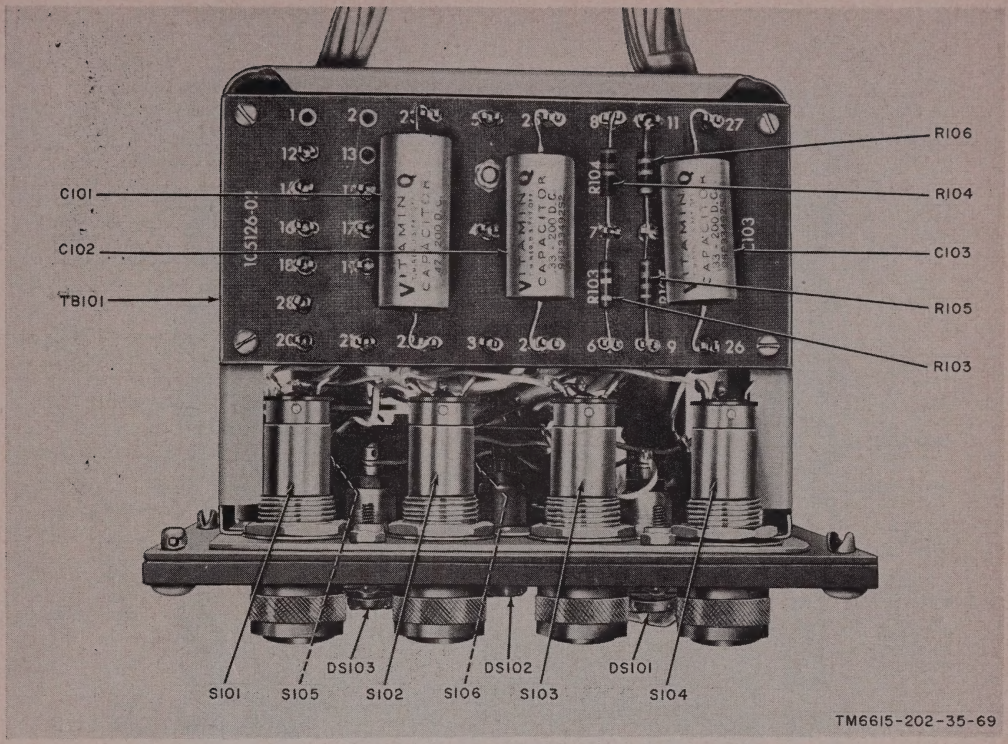


Figure 27. Control Panel Assembly Model No. 2560E, top view.

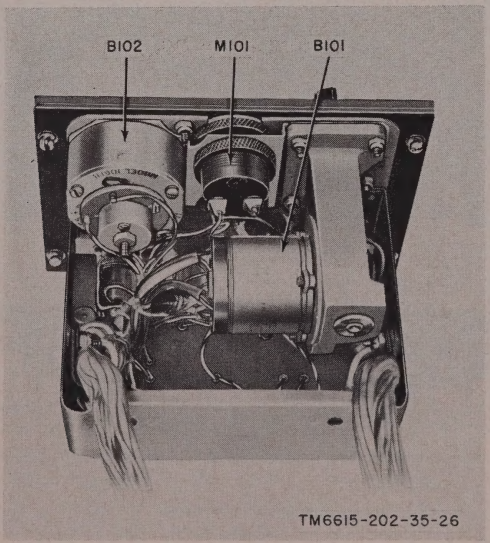


Figure 28. Control Panel Assembly Model No. 2560E, bottom view.

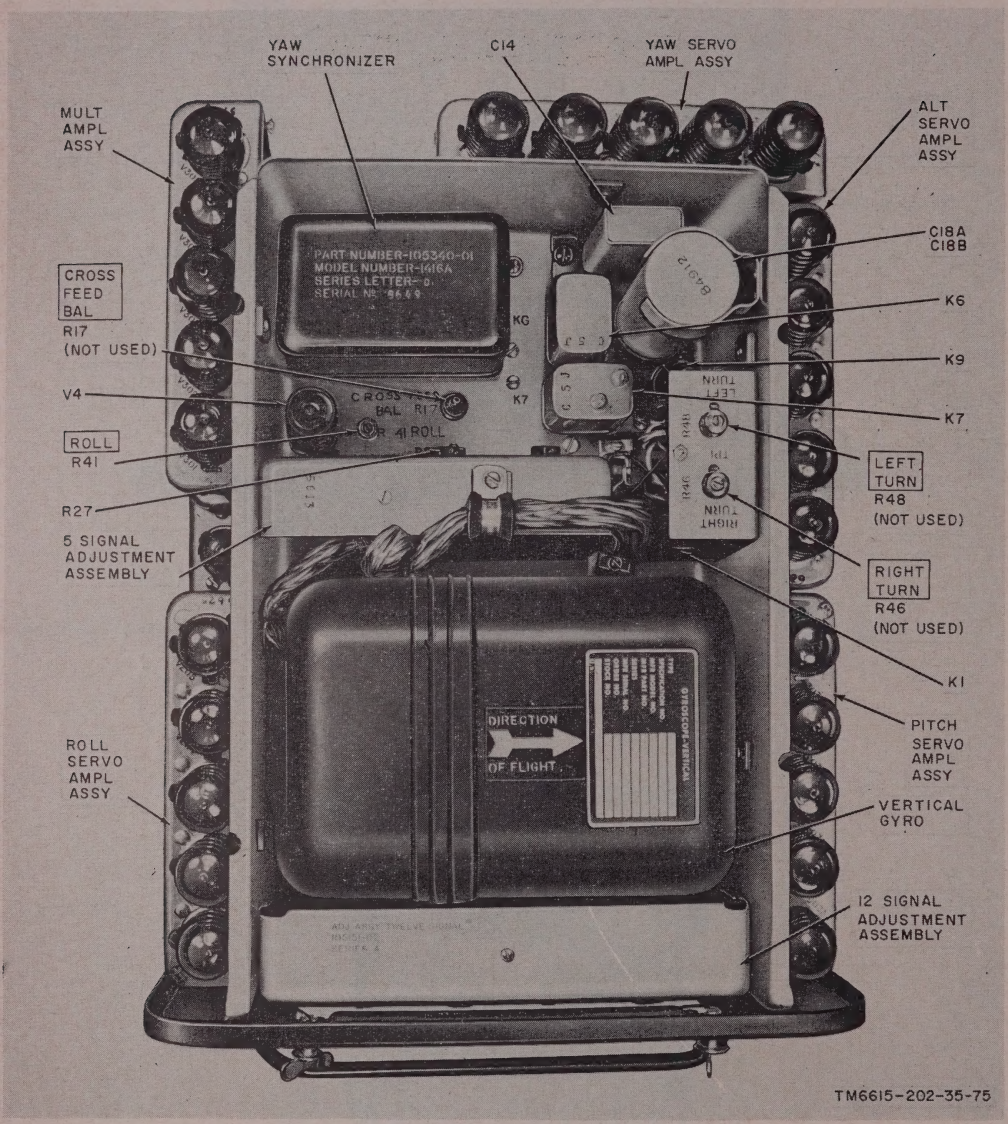


Figure 29. Control Gyro and Amplifier Assembly Model No. 1005N, top view, cover removed.

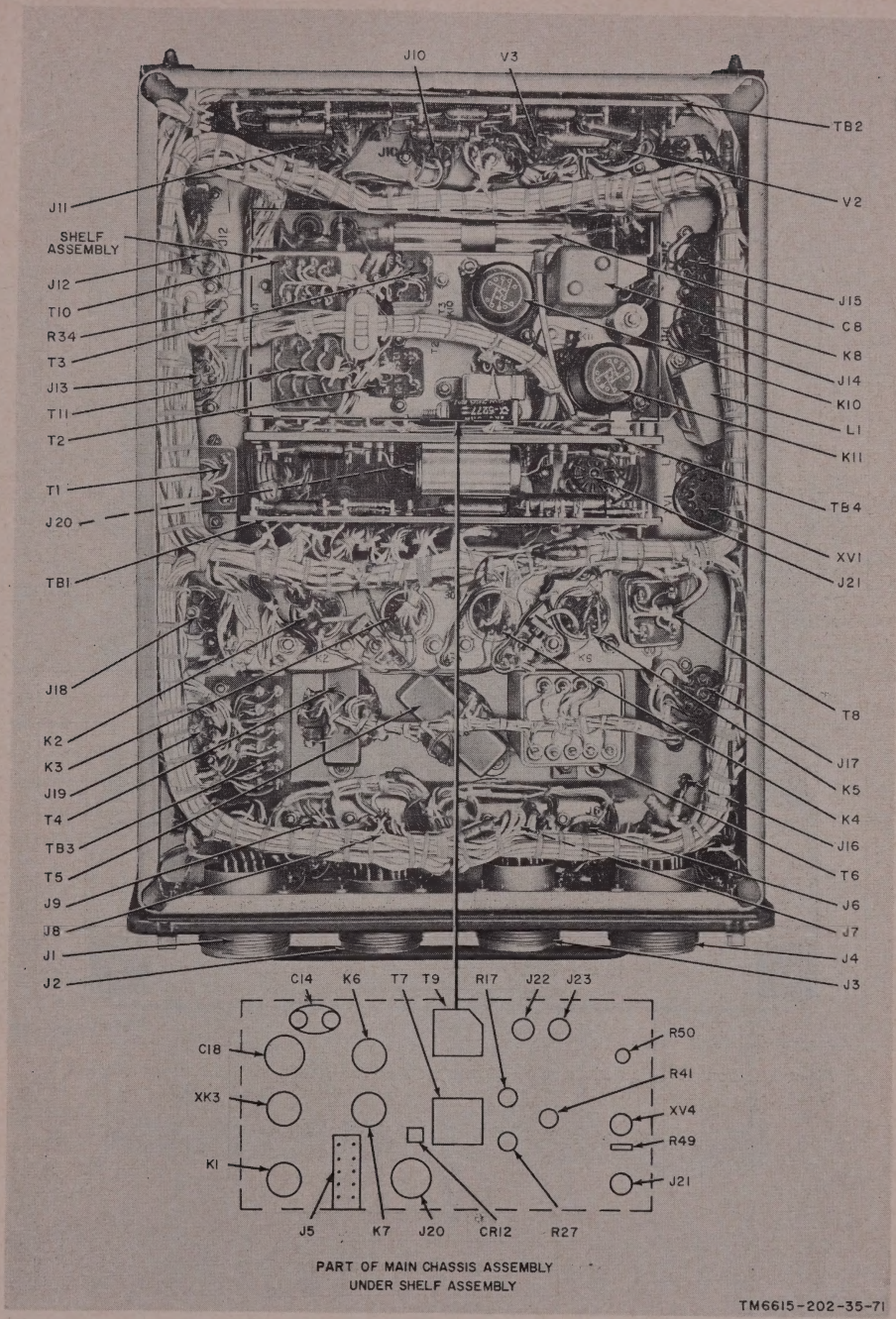


Figure 30. Control Gyro and Amplifier Assembly Model No. 1005N, bottom view, cover removed.

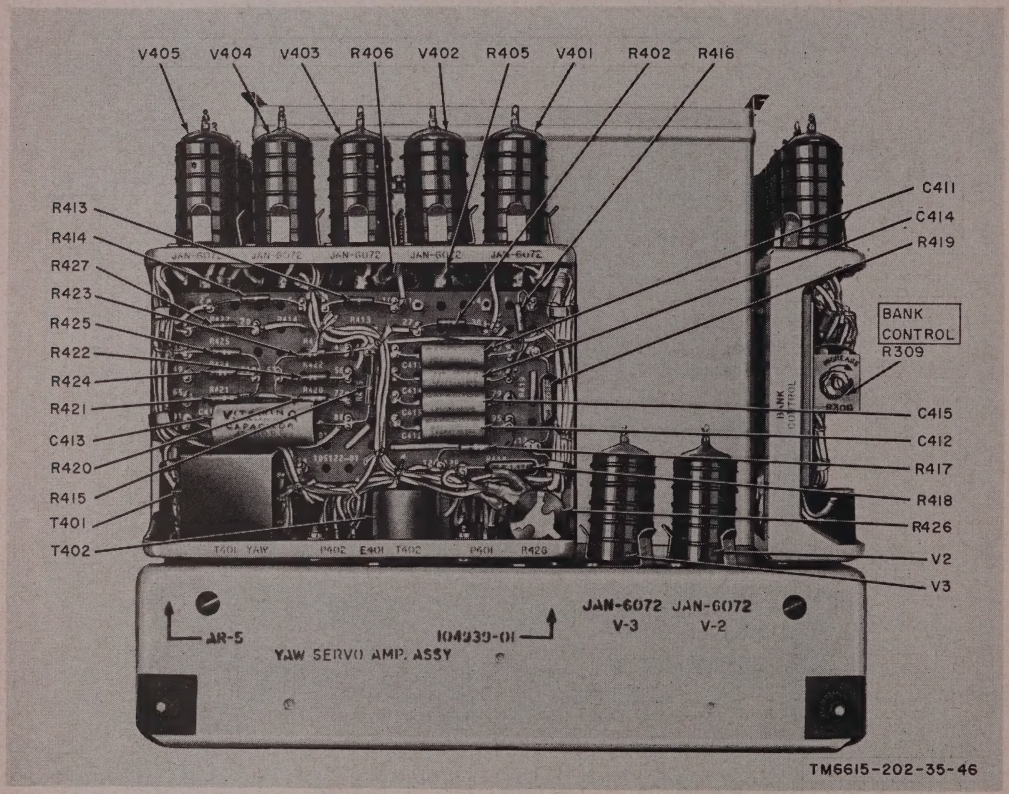


Figure 31. Control Gyro and Amplifier Assembly Model No. 1005N, rear view, cover removed.

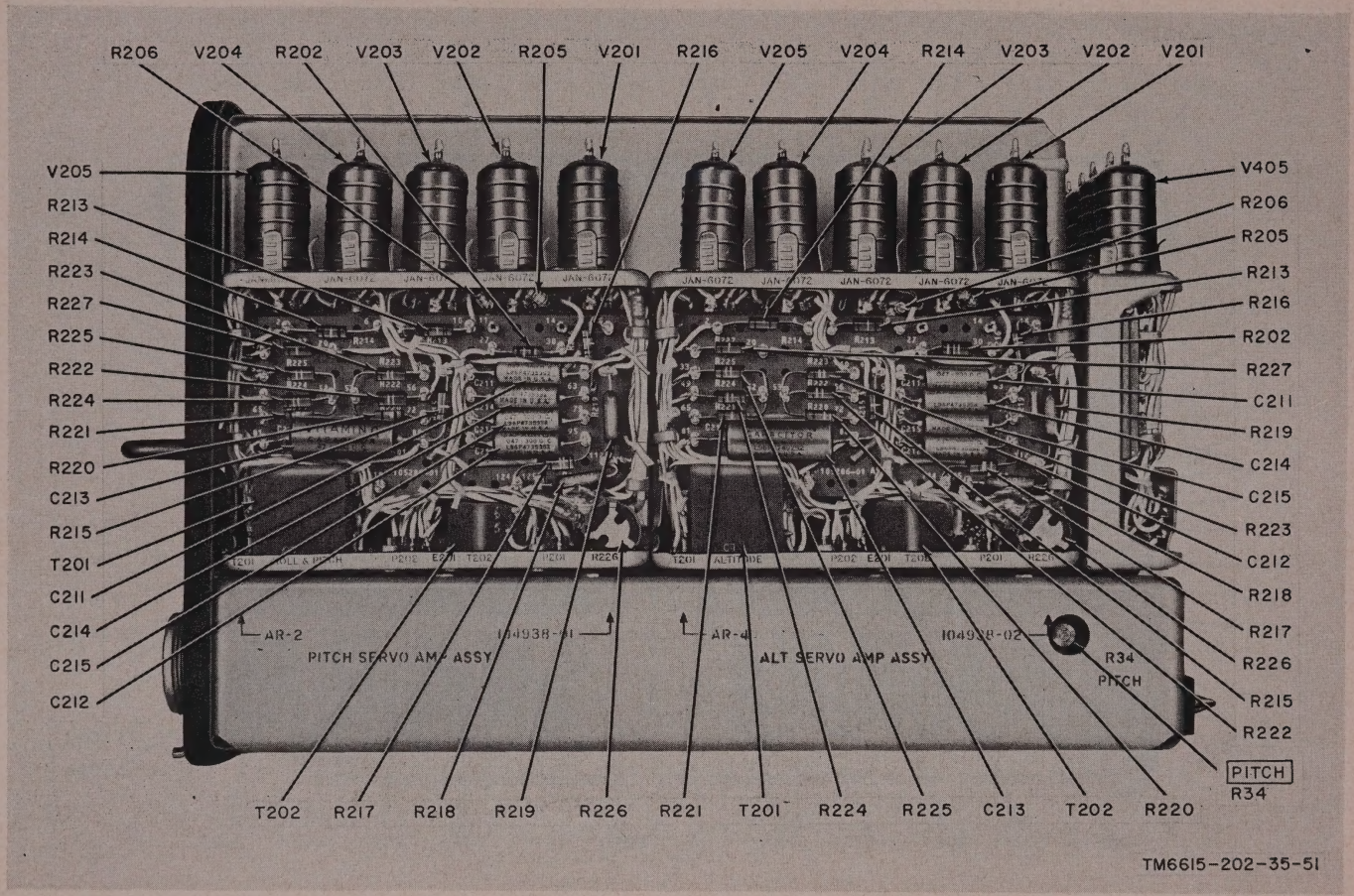


Figure 32. Control Gyro and Amplifier Assembly Model No. 1005N, right side view, cover removed.

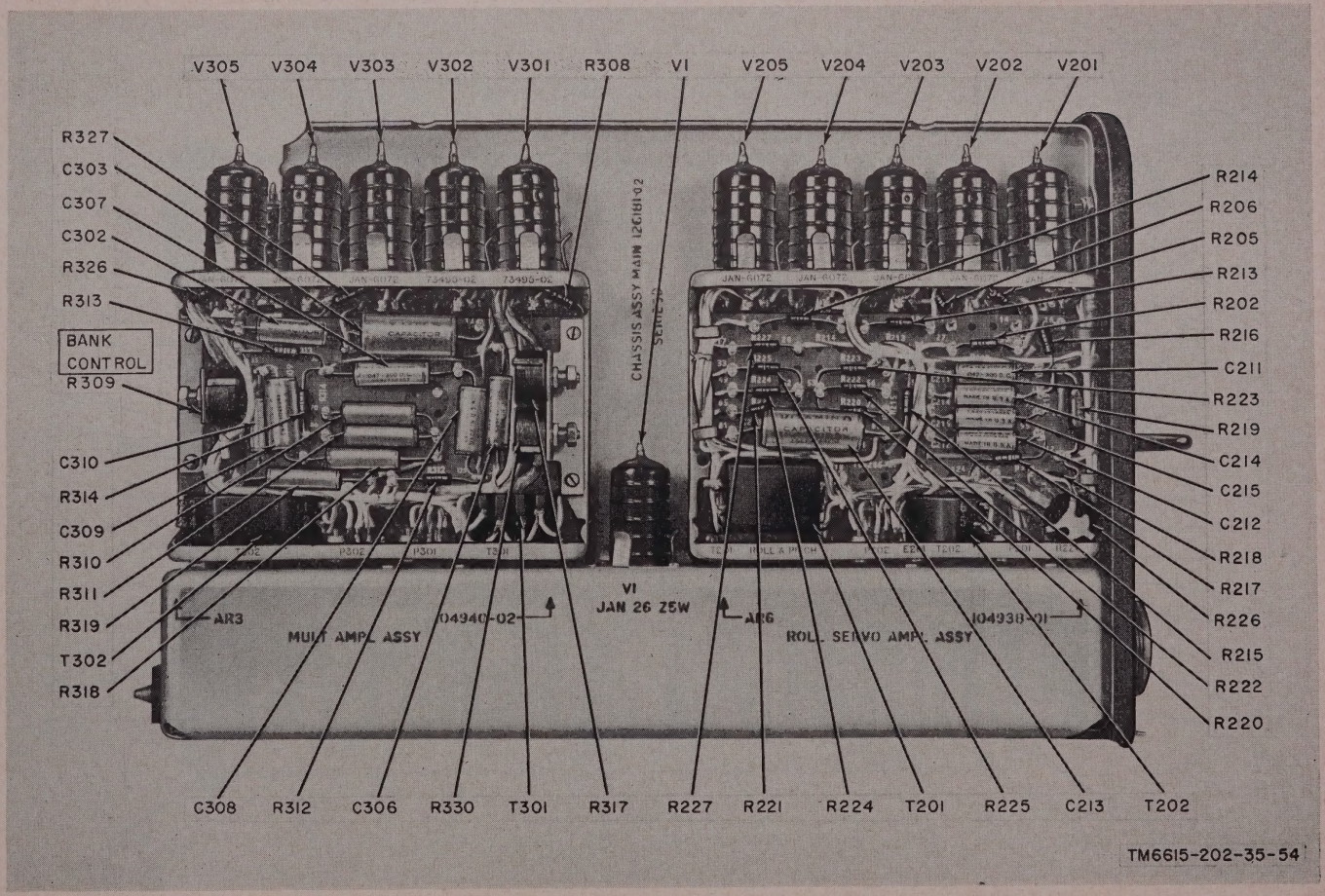
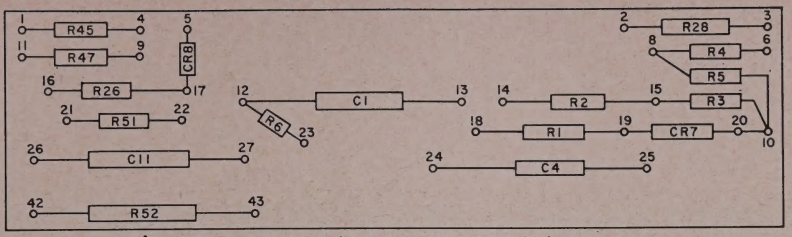
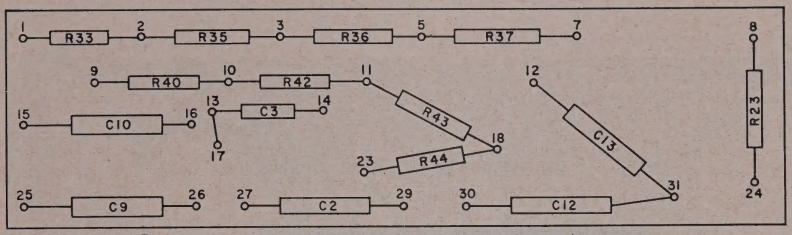


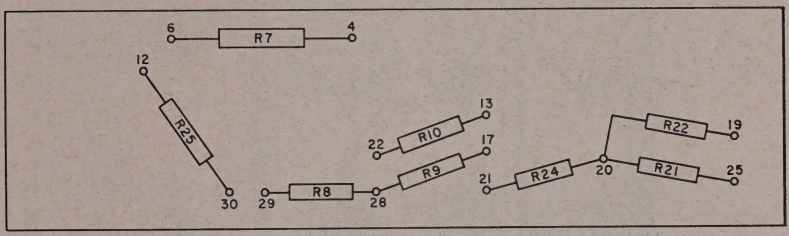
Figure 33. Control Gyro and Amplifier Assembly Model No. 1005N, left side view, cover removed.



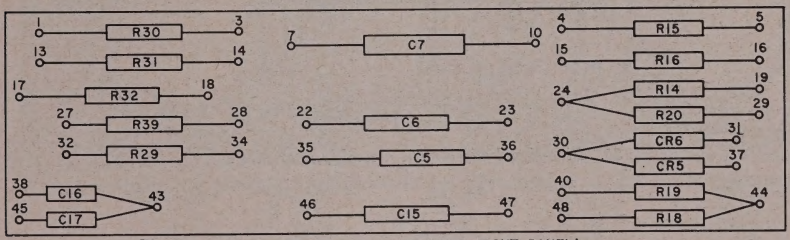
A. TERMINAL BOARD TB1 (SIDE NEAREST REAR PANEL)



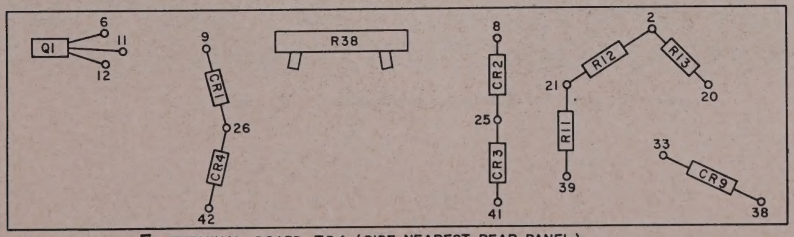
B. TERMINAL BOARD TB2 (SIDE NEAREST FRONT PANEL)



C. TERMINAL BOARD TB2 (SIDE NEAREST REAR PANEL)



D. TERMINAL BOARD TB4 (SIDE NEAREST FRONT PANEL)



E. TERMINAL BOARD TB4 (SIDE NEAREST REAR PANEL)

TM6615-202-35-99

Figure 34. Control Gyro and Amplifier Assembly Model No. 1005N, terminal boards TB1, TB2, and TB4, location of parts.

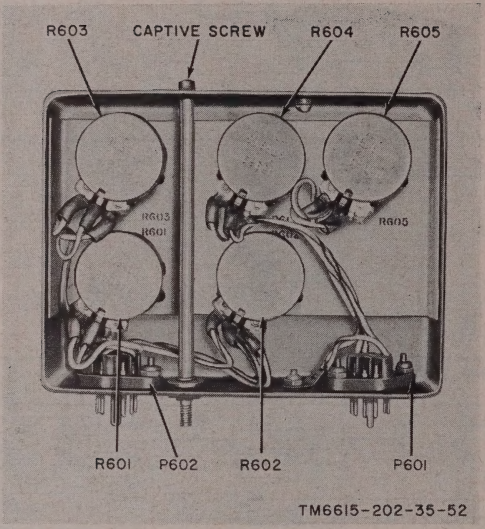


Figure 35. Five-signal adjustment assembly, rear view.

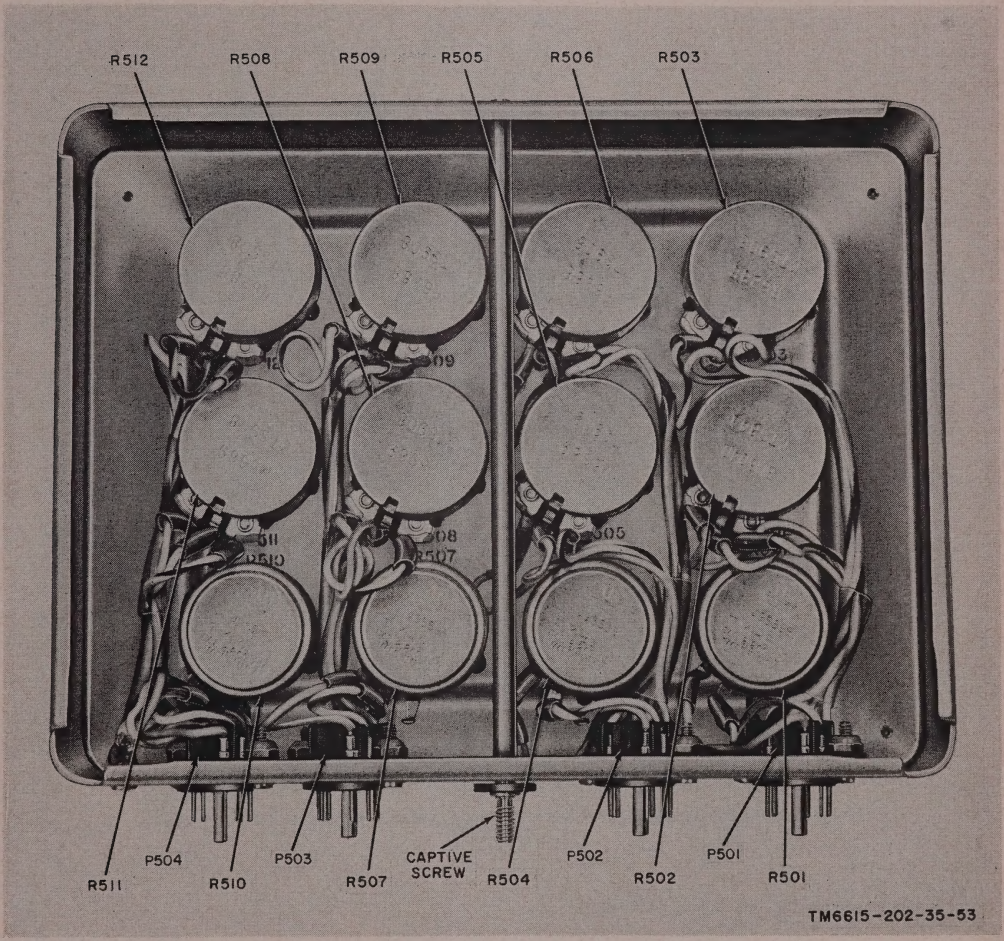


Figure 36. Twelve-signal adjustment assembly, rear view.

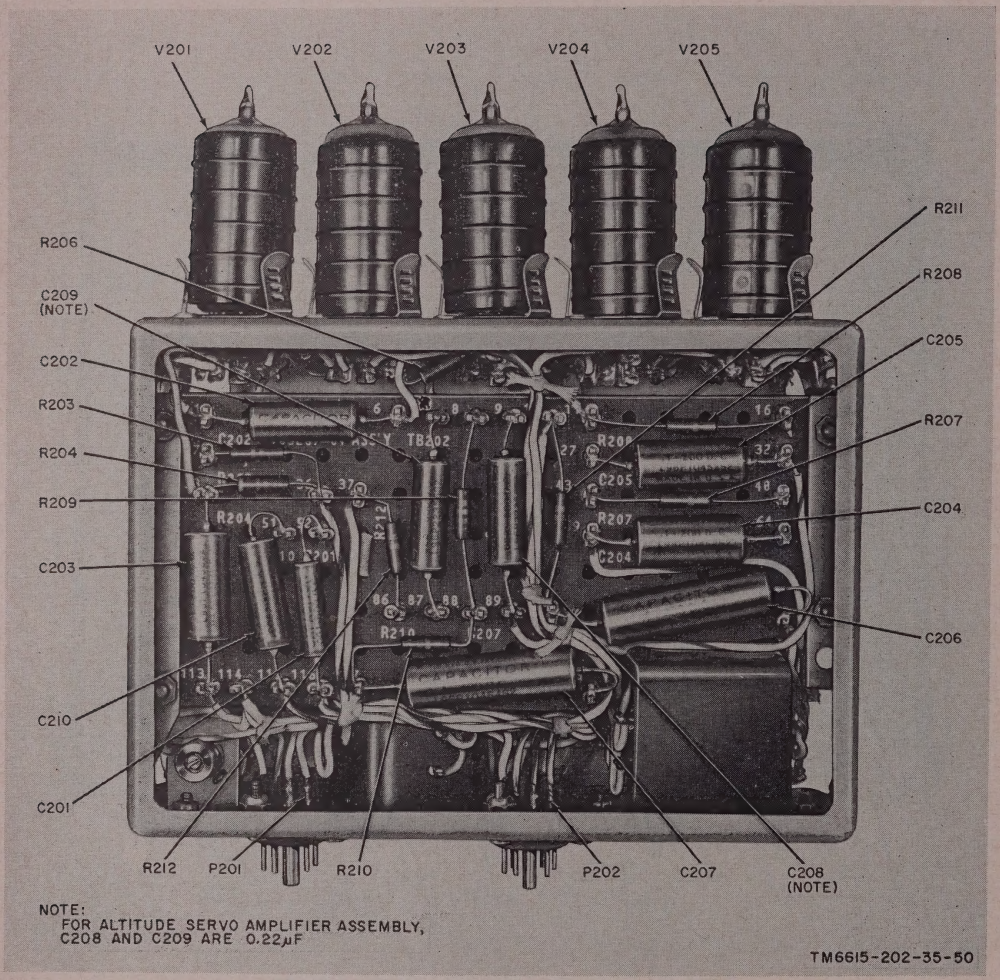


Figure 37. Pitch, roll, or altitude servo amplifier, rear view.

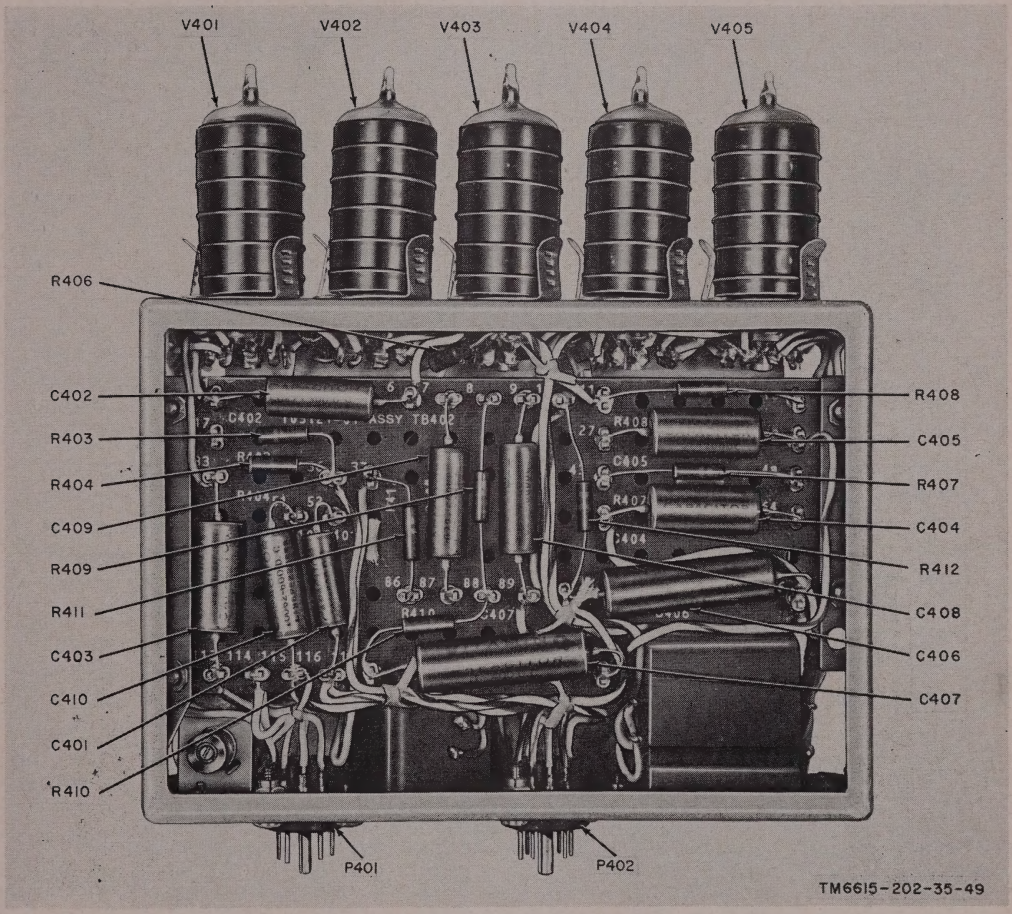


Figure 38. Yaw servo amplifier, rear view.

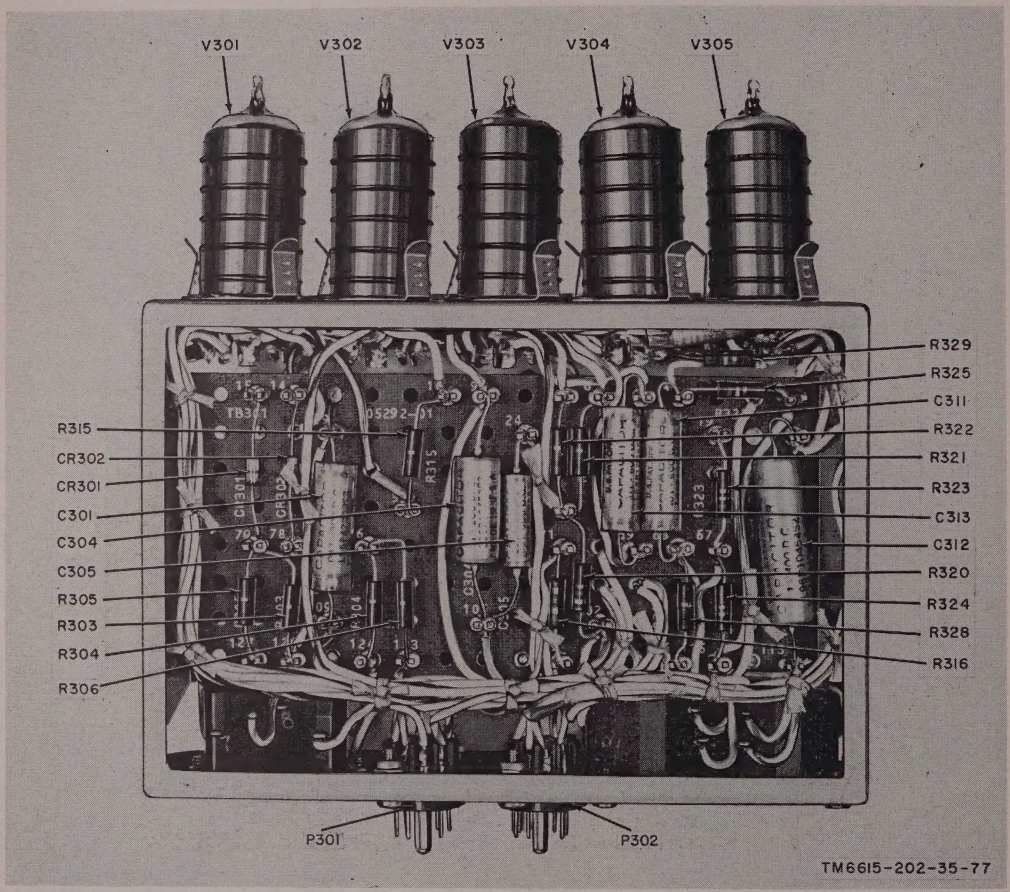


Figure 39. Multiple-channel amplifier, rear view.

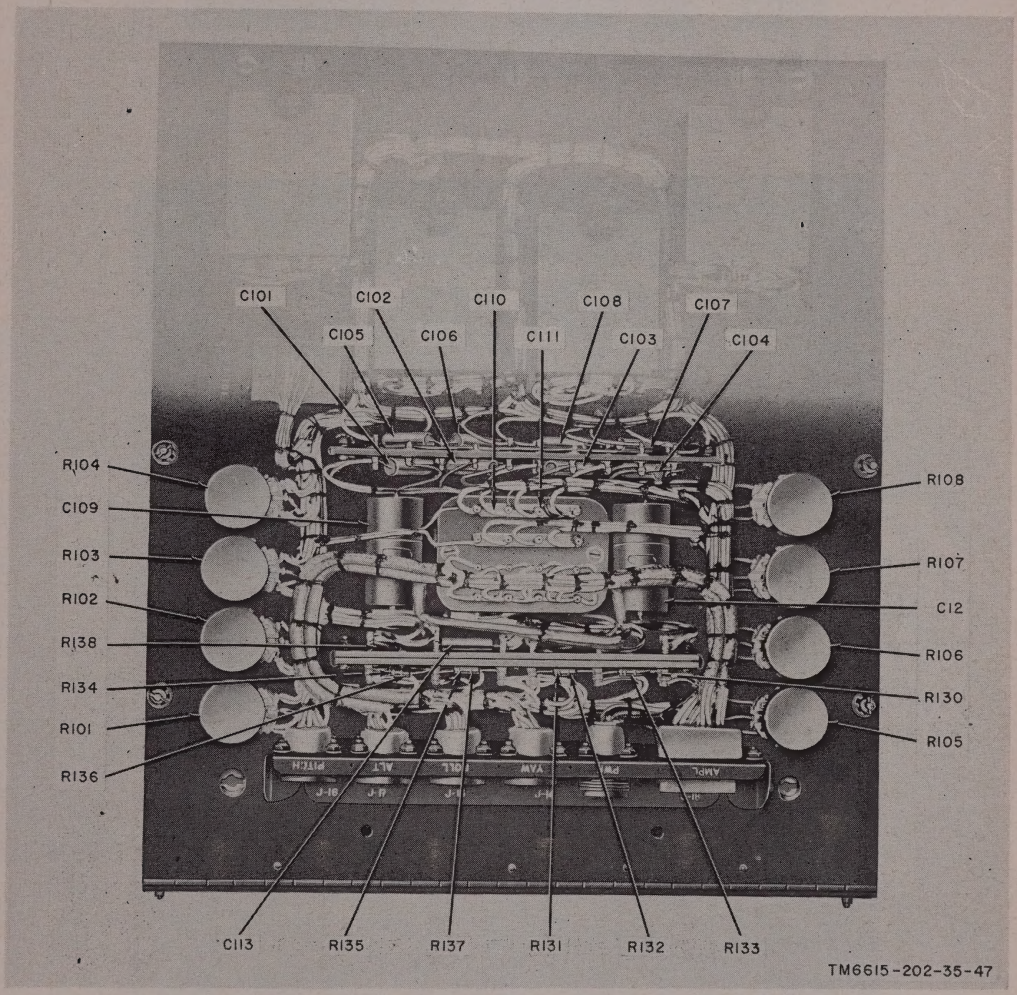


Figure 40. Motor Box Assembly Model No. S1645–61145–1 resistors and capacitors, rear view, cover removed.

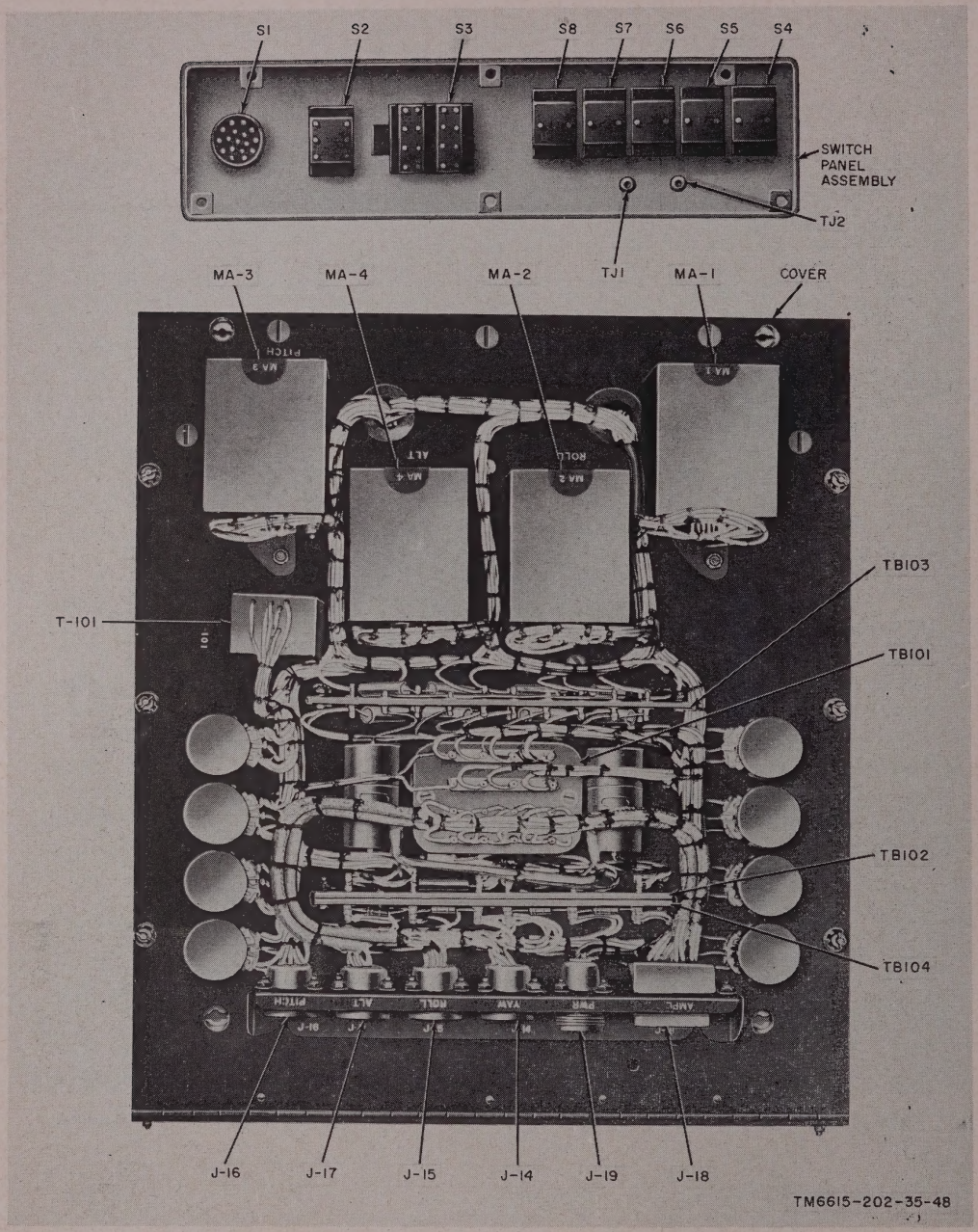


Figure 41. Motor Box Assembly Model No. S1645–61145–1 terminal boards, connectors, and magnetic amplifiers, rear view, cover removed.

CHAPTER 3

REPAIR AND ADJUSTMENTS

Section I. REPLACEMENT OF SYSTEM COMPONENTS

37. Control Panel Assembly Model No. 2560E

(fig. 42)

Note. The control panel assembly is located between the pilot and co-pilot on the radio console.

a. Removal.

(1) Loosen the four fasteners that secure the control panel assembly to the radio console.

(2) Raise the control panel assembly to gain

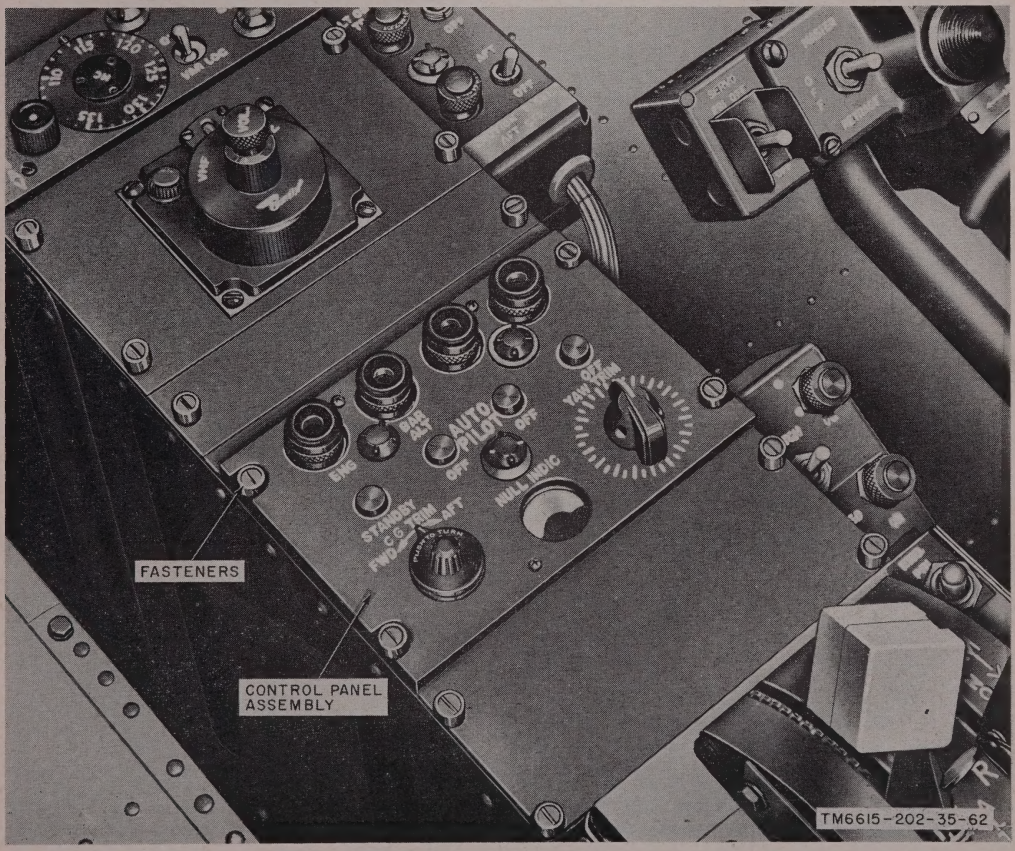


Figure 42. Replacement of control panel.

access to the electrical plugs (not shown). Cut the lockwire and disconnect the two electrical plugs.

b. Replacement.

(1) Connect the two electrical plugs to the back of the control panel assembly and install the lockwire.

(2) Insert the control panel assembly on the radio console and secure the control panel with the four fasteners.

Warning: **The control panel must be securely fastened to the radio console to prevent seepage of exhaust fumes into the cockpit.**

(3) Perform NULL INDIC meter adjustments (par. 53*a*(1) and (2)).

38. Control Gyro and Amplifier Assembly Model No. 1005N

(fig. 43)

Caution: **The control gyro and amplifier is mounted on the right-hand side of the transmission deck. Do not remove the unit until 10 minutes after disconnecting power from the autopilot. Damage to the vertical gyro assembly inside the unit may result.**

a. Removal.

(1) Open the right-hand service platform.

(2) Remove the cover.

(3) Cut and remove the lockwire securing the three electrical plugs.

(4) Loosen the two knurled nuts that secure the control gyro and amplifier to the shock mount assembly and slide the control gyro and amplifier from the shock mount.

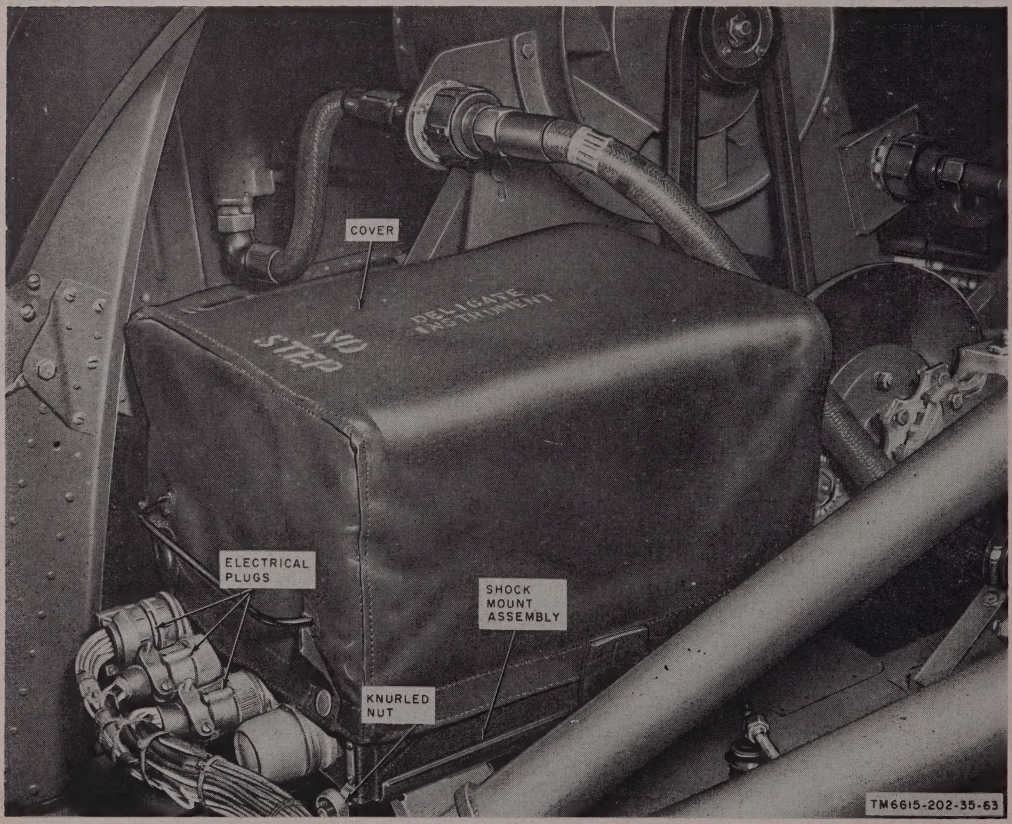


Figure 43. Replacement of control gyro and amplifier.

b. Replacement.

Note. Before installing a new control gyro and amplifier, check to see that the 5-signal and 12-signal adjustment assemblies are properly adjusted (par. 53*a* and *b*).

(1) Place the control gyro and amplifier on the shock mount assembly and secure it with the two knurled nuts.

(2) Connect the three electrical plugs to the control gyro and amplifier. Install lockwire on each plug.

(3) Replace cover.

(4) Close the right hand service platform.

39. Motor Box Assembly Model No. S1645–61145–1

(fig. 44)

Note. The motor box is mounted on the panel assembly between the pilot and copilot.

a. Removal.

(1) Loosen the three fasteners on each side of the motor box cover and lower the cover down on the hinge.

(2) Cut and remove the lockwire from each electrical plug on the rear of the motor box. Tag and disconnect the electrical plugs.

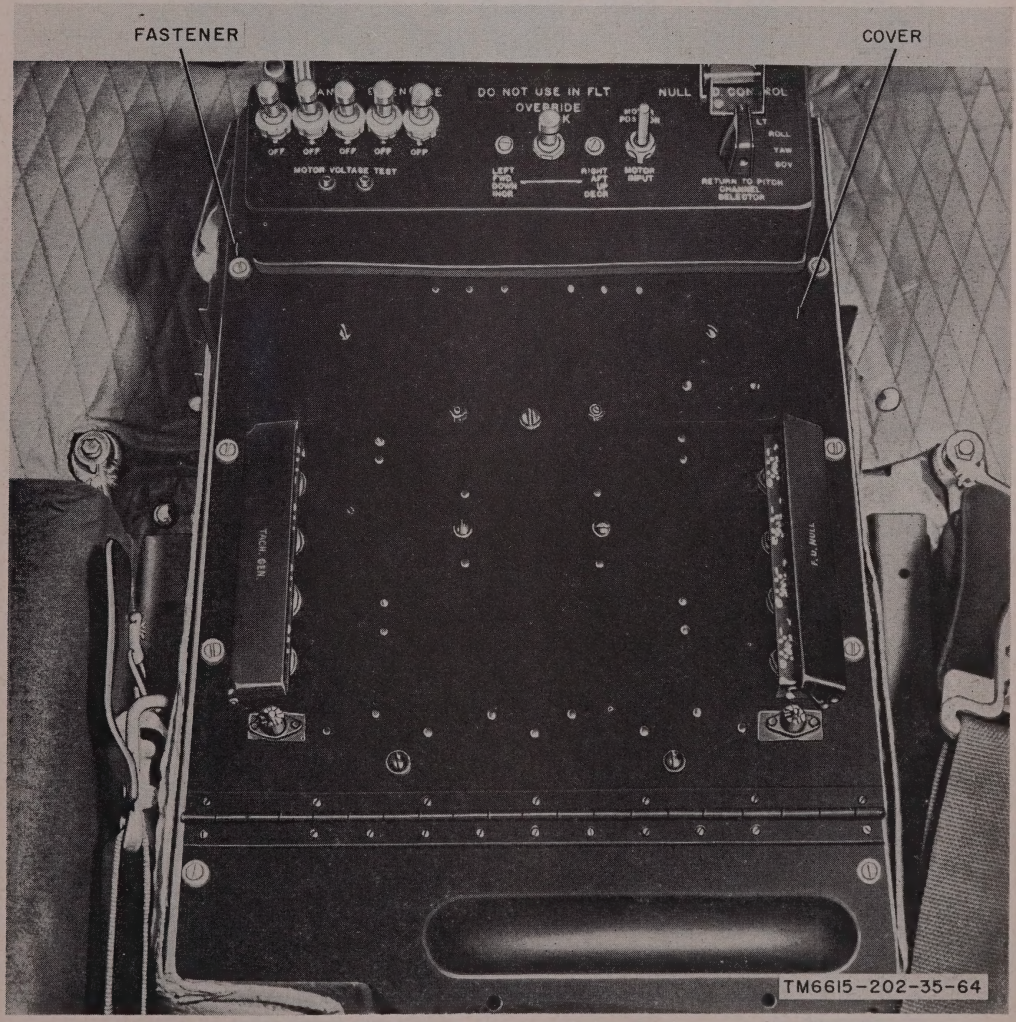


Figure 44. Replacement of motor box.

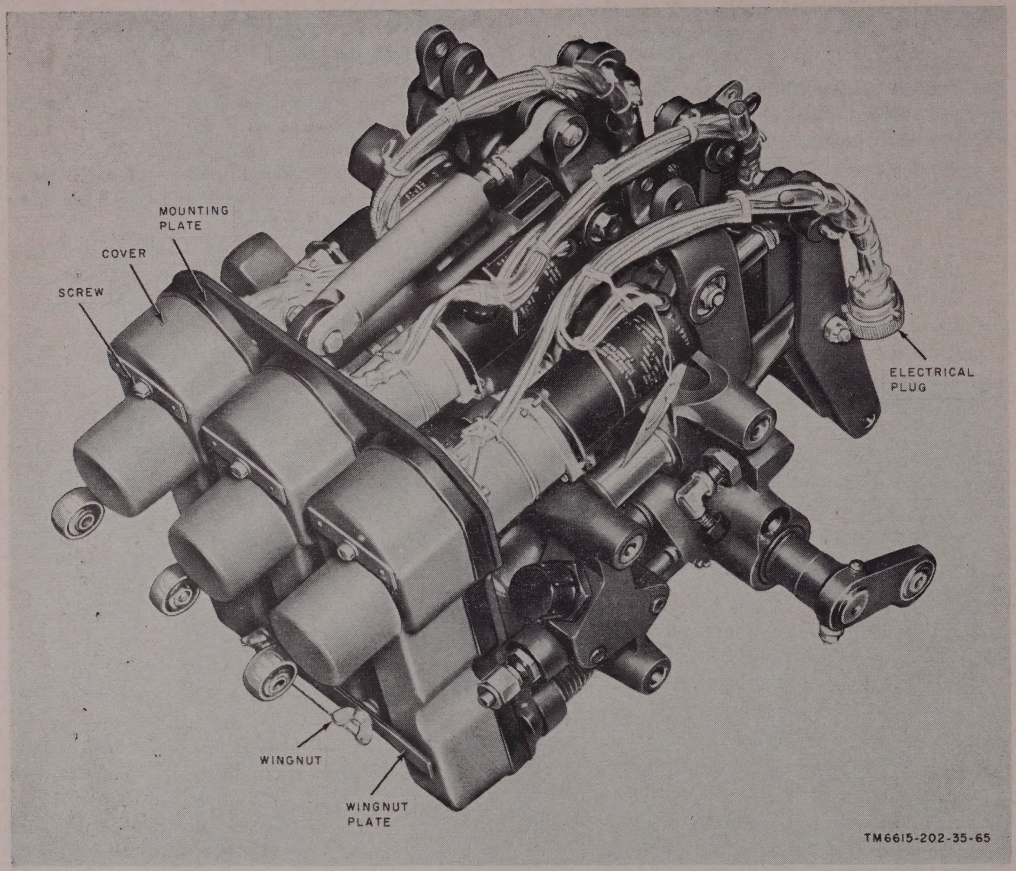


Figure 45. Replacement of pitch, roll, or altitude servo motor on the auxiliary servo unit.

(3) Raise the cover, loosen the remaining two fasteners and remove the motor box.

b. Replacement.

(1) Attach the motor box to the panel assembly with the two bottom fasteners.

(2) Connect the lockwire electrical plugs to the back of the motor box and remove the tags from the electrical plugs.

(3) Raise and secure the motor box with the three fasteners on each edge.

(4) Adjust the motor box TACH. GEN. and F. U. NULL potentiometers as described in paragraph 54.

40. Servo Motor Assembly Model No. S1665–61755

a. Removal of Pitch, Roll, or Altitude Servo Motor from Auxiliary Servo Unit (fig. 45).

Note. The roll, altitude, and pitch servo motor assemblies are mounted in the auxiliary servo unit. The auxiliary servo unit is located behind the motor box in the cockpit between the pilot's and copilot's seats.

(1) Remove the motor box assembly (par. 39).

(2) Remove the pilot's seat.

(3) Remove the panel assembly from the bulkhead to expose the auxiliary servo unit.

(4) Cut the lockwire and loosen the two wingnuts enough to swing the plate free of the servo motor cover.

(5) Remove the screw and washer that secures the servo motor cover to the auxiliary servo unit mounting plate and remove the the cover.

(6) Remove the screw that secures the servo motor to the auxiliary servo unit follow-up arm (not shown).

(7) Cut the lockwire and disconnect the electrical plug from the rear of the motor box (J14).

(8) Cut the lockwire and remove the four screws and washers (not shown) that secure the servo motor to the mounting plate.

(9) Carefully remove the servo motor and gasket from the auxiliary servo unit.

Caution: **Be extremely careful when removing the servo motor from the auxiliary servo unit to prevent damage to the mechanical linkage or to the servo unit gasket. The gasket should be retained with the auxiliary servo unit.**

b. Replacement of Pitch, Roll, or Altitude Servo Motor on Auxiliary Servo Unit (fig. 45).

Caution: **Be extremely cautious when installating the servo motor in the auxiliary servo unit to prevent damage to the mechanical linkage or servo unit gasket.**

(1) Carefully install the servo motor and gasket on the auxiliary servo unit and secure it with the four screws and washers.

(2) Connect the servo motor to the auxiliary servo unit followup arm.

(3) Connect the electrical plug (J14) to the motor box assembly.

(4) Perform the appropriate F. U. NULL and TACH. GEN. adjustments as described in paragraph 54.

(5) After completion of the adjustments disconnect the electrical plug from the motor box.

(6) Lockwire the servo motor mounting screws.

(7) Install the servo motor cover and secure the cover to the mounting plate with the screws and washers.

(8) Place the wingnut plate against the servo motor cover, tighten and lockwire the wingnuts.

(9) Replace the panel assembly on the bulkhead.

(10) Replace the pilot's seat.

(11) Replace the motor box assembly.

(12) Connect the electrical cable to the motor box and lockwire the cable.

c. Removal of Yaw Servo Motor from the Tail Rotor Servo Unit (fig. 46).

Note. The tail rotor servo unit is located on the left side of the transmission deck, aft of the main gear box.

(1) Open the left-hand service platform.

(2) Remove the left-hand access panel.

(3) Cut the lockwire and remove the electrical plug.

(4) Cut the lockwire and remove the screws and washers that secure each side of the servo motor cover to the mounting plate.

(5) Pull the cover away from the servo motor and remove the screw that secures the servo motor to the tail rotor servo unit followup arm (not shown).

(6) Cut the lockwire and remove the four screws that secure the servo motor and the tail rotor to the servo unit mounting plate (not shown).

(7) Carefully remove the servo motor assembly from the tail rotor servo unit.

Caution: **Exercise extreme caution when removing the servo motor from the tail rotor servo unit to prevent damage to the mechanical linkage or servo unit gasket. The gasket should be retained with the tail rotor servo unit.**

d. Replacement of Servo Motor on Tail Rotor Servo Unit (fig. 46).

Caution: **Be extremely careful when installing the servo motor on tail rotor servo unit to prevent damage to the mechanical linkage or servo unit gasket.**

(1) Carefully replace the servo motor and gasket and secure the servo motor to the tail rotor servo unit with the screws and washers (not shown).

(2) Connect the servo motor to the tail rotor servo unit followup arm.

(3) Connect the servo motor electrical plug.

(4) Perform the yaw F. U. NULL and TACH. GEN. adjustments described in paragraph 54.

(5) After completion of the adjustments, lockwire the electrical plug and screws that secure the servo motor.

(6) Install the servo motor cover. Secure the cover to the mounting plate with screws and washers. Install the lockwire on screws.

(7) Install the left-hand access panel.

(8) Close up the left-hand service platform.

41. Altitude Control Assembly Model No. 2203G

(fig. 47)

Note. The altitude control is located in the electronics compartment.

a. Removal.

(1) Disconnect static port tubing from the altitude control adapter.

(2) Cut the lockwire and disconnect the electrical plug.

(3) Remove the screws, washers, and nuts that secure the altitude control shock mount to the shelf and remove the shock mount and the altitude control.

(4) Remove electrical connector assembly from the shock mount.

(5) Loosen the wingnut to allow altitude control to be removed from the shock mount.

Caution: **Keep all static lines clean to prevent damage to the altitude control. Do not blow into the altitude control to clean it out.**

b. Replacement.

Note. When replacing the altitude control, be sure that the nameplate is approximately horizontal relative to the floor of the aircraft.

(1) Slide the altitude control into the shock mount and secure the control with the metal strap and wingnut.

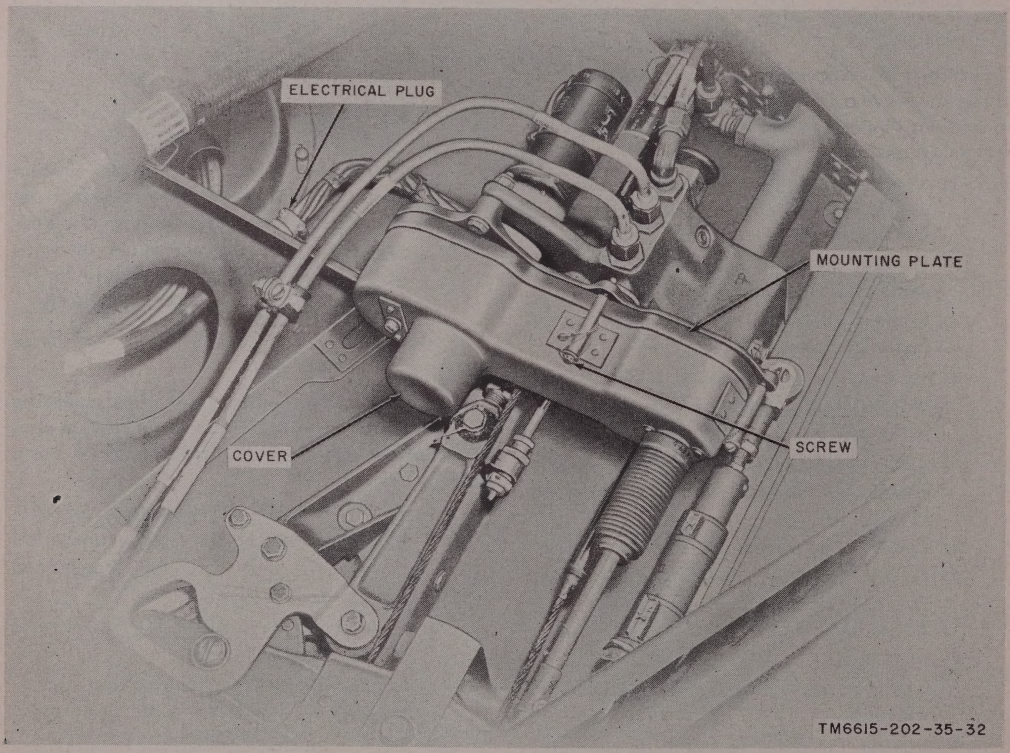


Figure 46. Replacement of yaw servo motor on the tail rotor servo unit.

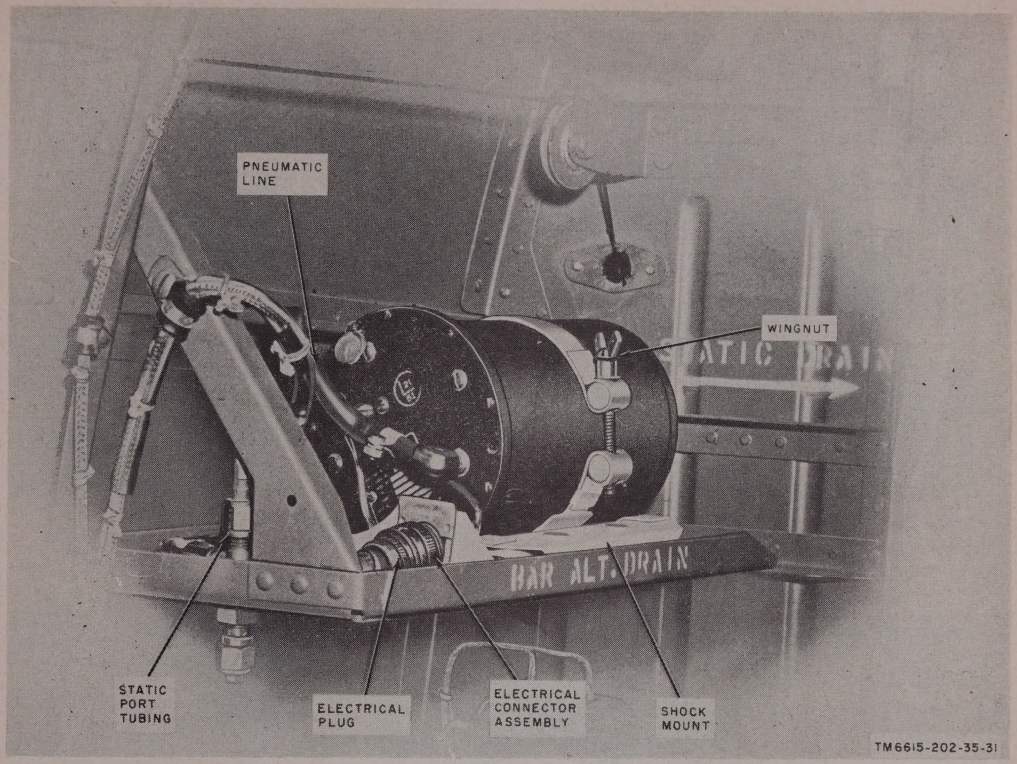


Figure 47. Replacement of altitude control assembly.

(2) Install the electrical connector assembly on the shock mount.

(3) Place the shock mount on the shelf and secure the shock mount with the screws, washers, and nuts.

(4) Connect electrical plug to the altitude control, and replace the lockwire on the electrical plug.

(5) Connect the static port tubing to the adapter on the altitude control.

42. Control Stick Canceller Assembly Model No. 911D

(fig. 48)

Note. The cancellers (pitch and roll) are located in the right-hand side of the clutch fan compartment. The pitch canceller is mounted on the outboard support assembly and the roll canceller is mounted on the inboard support assembly. Access to the cyclic control stick cancellers is gained through the clutch access door in the center of the cabinet forward bulkhead.

a. Removal.

(1) Open the clutch fan access door.

(2) Cut the lockwire and remove the electrical plug.

(3) Cut the lockwire and loosen the screws and washers (not shown) that secure the shaft of the canceller to the crank arm.

(4) Remove the three mounting screws, washers, and nuts that secure the canceller to the support assembly and remove the canceller by sliding the canceller shaft out of the crank arm and support assembly.

b. Replacement.

Note. Install the rigging pins in the cyclic control stick yokes so that the sticks are locked in neutral position. Check stick movement due to tolerances on the rigging pins. If there is excessive play, move the stick to the center position. Check to see that the three red dots (two on the canceller housing and one on the shaft) are alined.

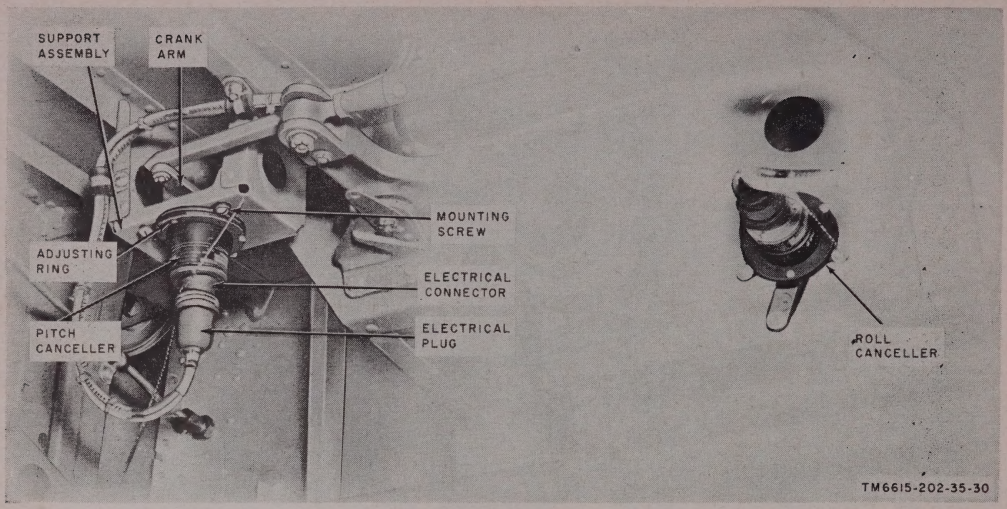


Figure 48. Replacement of control stick canceller.

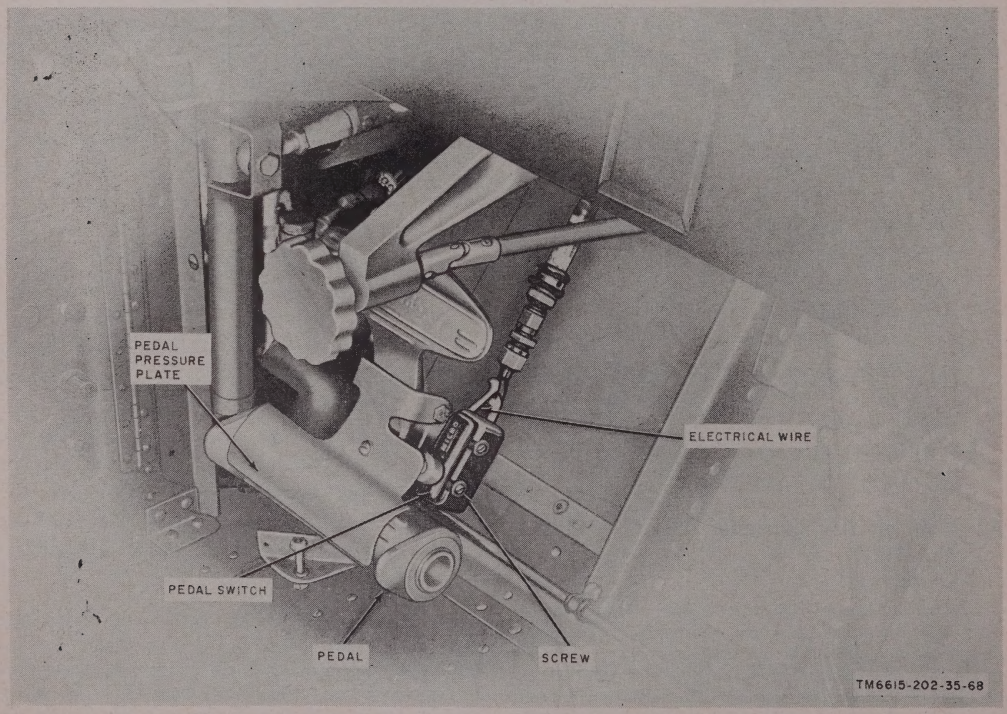


Figure 49. Replacement of tail rotor pedal switches.

Caution: **Do not install the crank arm supplied with the new canceller. The crank arm supplied will not fit this installation.**

(1) Install the canceller on the support assembly. Be sure the canceller shaft is inserted in the crank arm.

(2) Attach the canceller to the support assembly with the three mounting screws, washers, and nuts.

(3) Tighten and lockwire the screws on the crank arm.

(4) Connect the electrical plug to the electrical connector and lockwire the plug.

(5) Adjust the control stick canceller as described in paragraph 56.

43. Pilot's and Copilot's Tail Rotor Pedal Switches

(fig. 49)

Note. The pedal switches are located on each of the tail rotor control pedals.

a. Removal.

(1) Remove the two screws, washers, and nuts that secure the pedal switch to the pedal.

(2) Remove the two electrical wires from the pedal switch.

b. Replacement.

(1) Connect the two electrical wires to the pedal switch.

(2) Secure the pedal switch to the pedal with the two screws, washers, and nuts.

(3) Check to see that the pedal switch is actuated when pressure is applied to the pedal pressure plate.

44. Time Delay Relay (Motor Release) and Emergency Release Relay

(fig. 50)

Note. The time delay relay and the emergency release relay are located on the aft right-hand side of the canted bulkhead, above the transmission deck.

a. Removal.

(1) Open the right-hand service platform.

(2) Remove the two screws that secure the time delay relay or nuts (not shown) that secure the emergency release relay to the bracket and remove the relay.

(3) Tag and unsolder the electrical wires from the relay.

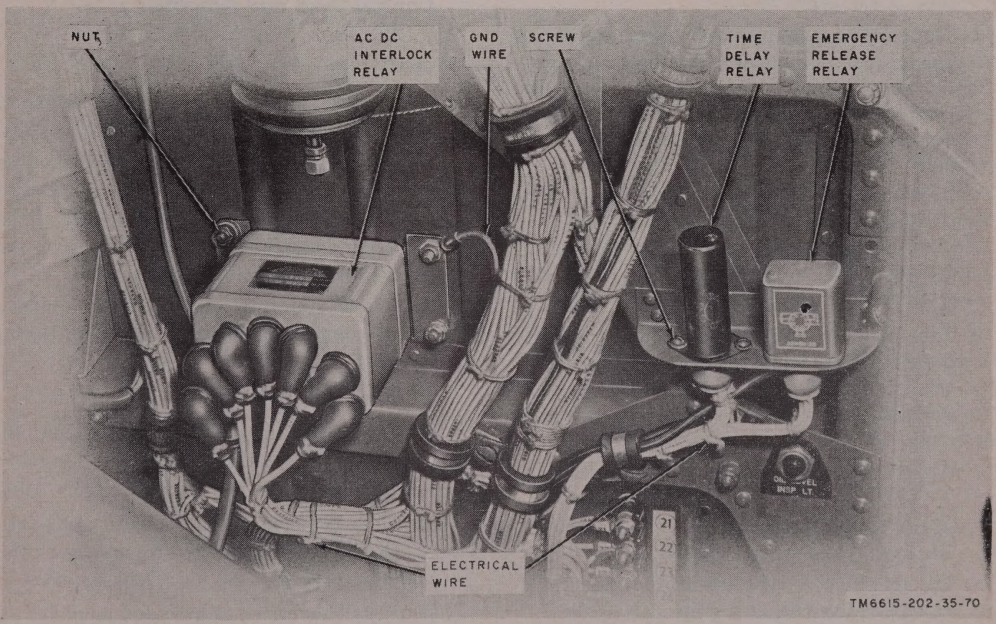


Figure 50. Replacement of time delay relay, emergency release relay, and AC-DC interlock relay.

b. Replacement.

(1) Solder the electrical wires to the relay, and remove the tags.

(2) Mount and secure the relay to the bracket.

(3) Adjust the time delay relay as described in paragraph 55. The emergency release relay does not require adjustment.

(4) Close the right-hand service platform.

45. AC-DC Interlock Relay

(fig. 50)

Note. The AC-DC interlock relay is located on the aft right-hand side of the canted bulkhead above the transmission deck.

a. Removal.

(1) Open the right-hand service platform.

(2) Tag the electrical wires and remove the wires from AC-DC relay.

(3) Remove the four nuts and washers that secure the relay to the bulkhead.

(4) Remove the ground wire from the stud and remove the relay.

b. Replacement.

(1) Place the relay against the bulkhead and connect the ground wire to the stud.

(2) Secure the relay to the bulkhead with the four nuts and washers.

(3) Connect the electrical wires to the relay terminal posts.

(4) Remove the tags from wires.

(5) Close the right-hand service platform.

Section II. REPAIR OF SYSTEM COMPONENTS

46. Scope

a. Procedures for replacing subassemblies on the control gyro and amplifier are described in paragraphs 47 through 51. Special procedures for replacement of detailed parts on the control panel, motor box, and control gyro and amplifier are described in paragraph 52.

b. Disassembly and reassembly procedures are not provided in this manual for the components listed in (1) through (4) below. Special tools, fixtures, and test equipments, required for disassembly, reassembly, and testing of these components are not available.

(1) Servo motor assembly, model No. S1665–61755.

(2) Control stick canceller, model No. 911D.

(3) YAW TRIM control B101.

(4) C G TRIM control B102.

c. The following autopilot components are replaced as complete units. They are not repaired by Signal Corps personnel and must be returned, through maintenance channels, to the manufacturer for repair.

(1) Altitude control assembly, model No. 2203G.

(2) Vertical gyro assembly.

(3) Yaw synchronizer assembly.

d. The following components are not repairable and are replaced as complete units:

(1) Tail rotor pedal switches.

(2) Time delay relay.

(3) Emergency release relay.

(4) AC-DC interlock relay.

47. Replacement of Servo Amplifier and Multiple Channel Amplifier Assemblies, Control Gyro and Amplifier

(fig. 51)

a. Removal.

(1) Remove the control gyro and amplifier from the shock mount assembly (par. 38*a*).

(2) Loosen the two Dzus fasteners on the rear of the dust cover assembly (8) and the two Dzus fasteners on the front panel of the main chassis assembly (24). Remove the dust cover assembly.

(3) Loosen the captive screw (10) and remove the appropriate amplifier assembly (9, 11, 12, 13, or 25).

b. Replacement.

(1) Install the amplifier assembly (9, 11, 12, 13, or 25) on the main chassis assembly (24) and secure it with captive screw (10).

(2) Slide the main chassis assembly (24) into the dust cover assembly (8), and secure the dust cover with the four Dzus fasteners.

(3) Install the cover of gyro and amplifier on the shock mount assembly (par. 38*b*).

48. Replacement of Yaw Synchronizer Assembly, Control Gyro and Amplifier (fig. 51)

a. Removal.

(1) Remove the control gyro and amplifier from the shock mount assembly (par. 38*a*).

(2) Loosen the two Dzus fasteners on the rear of the dust cover assembly, (8) and the two Dzus fasteners on front panel of the main chassis assembly (24); remove the dust cover.

(3) Remove the bottom dust cover assembly (not shown).

(4) Loosen captive screws (10) and remove altitude servo amplifier (11) and multiple-channel amplifier (12) to gain access to the screws securing the shelf assembly (fig. 30).

(5) Remove the four screws that secure the shelf assembly.

(6) Lift the shelf assembly out of its position and to one side of the main chassis.

(7) Remove screw (20), nut (21), and bracket (19) (fig. 51).

(8) Remove the two nuts (23) that secure the yaw synchronizer assembly (22) to the mating sprocket on the main chassis assembly (24).

(9) Remove the yaw synchronizer assembly.

b. Replacement.

(1) Place the yaw synchronizer assembly (22) on the main chassis assembly (24).

(2) Replace the two nuts (23) to secure the yaw synchronizer assembly to the mating socket on main chassis assembly.

(3) Replace screw (20), nut (21), and bracket (19).

(4) Reposition the shelf assembly and secure it with four screws.

(5) Install the multiple-channel amplifier (12) and the altitude servo amplifier (11) and secure each with captive screws (10).

(6) Replace the bottom dust cover assembly (not shown).

(7) Slide the main chassis assembly (24) into the dust cover assembly (8), and secure the dust cover with the Dzus fasteners.

(8) Install the control gyro and amplifier on the shock mount assembly (par. 38*b*).

49. Replacement of Five-signal Adjustment Assembly, Control Gyro and Amplifier (figs. 51 and 53)

a. Removal.

(1) Remove the control gyro and amplifier from the shock mount assembly (par. 38*a*).

(2) Loosen the two Dzus fasteners on the rear of the dust cover assembly (8, fig. 51) and the two Dzus fasteners on the front panel of the main chassis assembly (24). Remove the dust cover assembly.

(3) Loosen locking screw (10, fig. 53) and remove the five-signal adjustment assembly (16, fig. 51).

b. Replacement.

(1) Place the five-signal adjustment assembly (16, fig. 51) in the control gyro and amplifier, and secure it with locking screw (10, fig. 53).

(2) Slide the main chassis assembly (24, fig. 51) into the dust cover assembly (8), and secure the dust cover with the four Dzus fasteners.

(3) Install the control gyro and amplifier on the shock mount assembly (par. 38*b*).

50. Replacement of 12-signal Adjustment Assembly, Control Gyro and Amplifier (figs. 51 and 54)

a. Removal.

(1) Remove the control gyro and amplifier from the shock mount assembly (par. 38*a*).

(2) Loosen the two Dzus fasteners on the rear of dust cover assembly (8, fig. 51) and the two Dzus fasteners on the front panel of main chassis assembly (24). Remove the dust cover assembly.

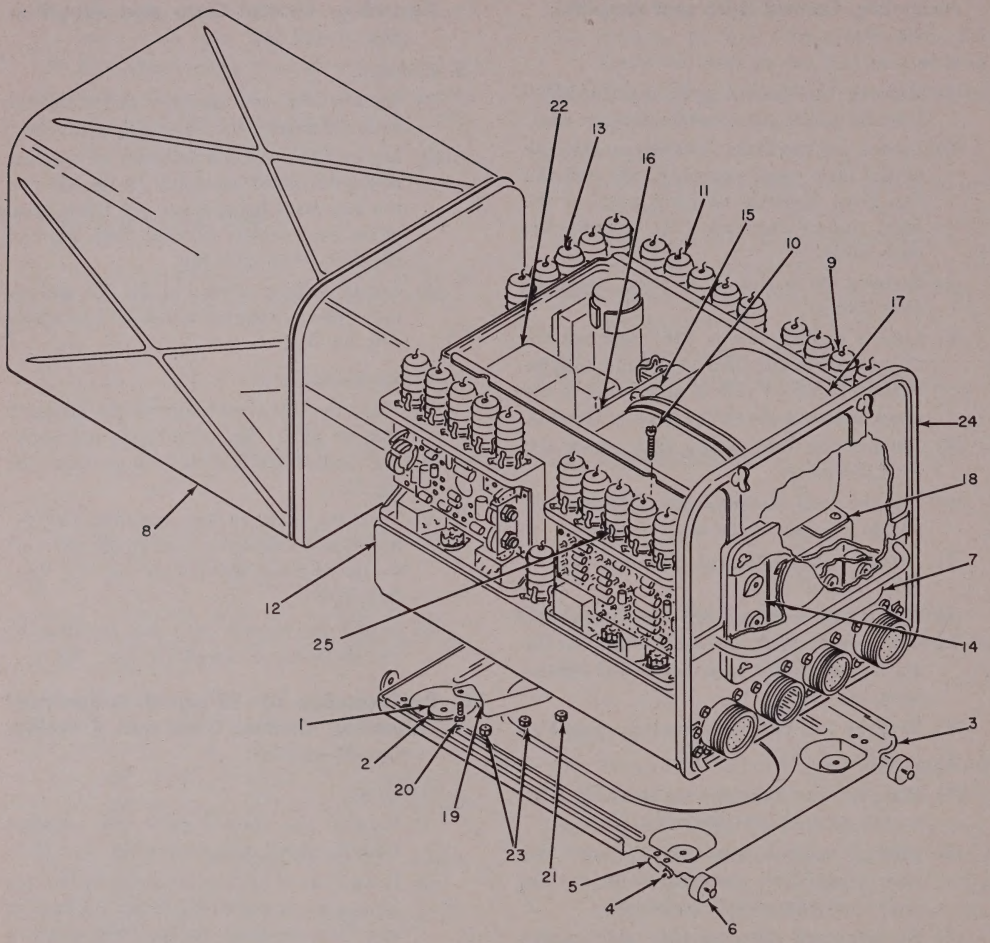
(3) Remove the adjustment box cover assembly (7).

(4) Loosen the locking screw (10, fig. 54), and remove the 12-signal adjustment assembly (14, fig. 51).

b. Replacement.

(1) Place the 12-signal adjustment assembly in the control gyro and amplifier, and secure with locking screw (10, fig. 54).

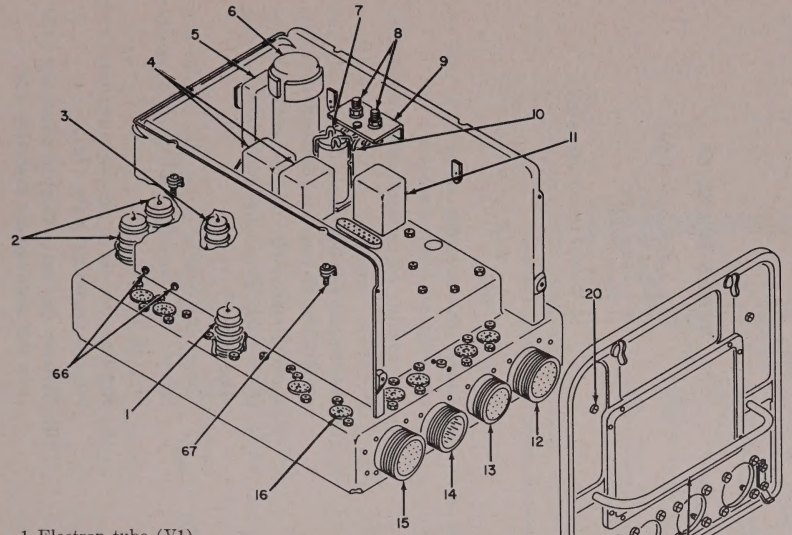
(2) Replace the adjustment box cover assembly (7, fig. 51).

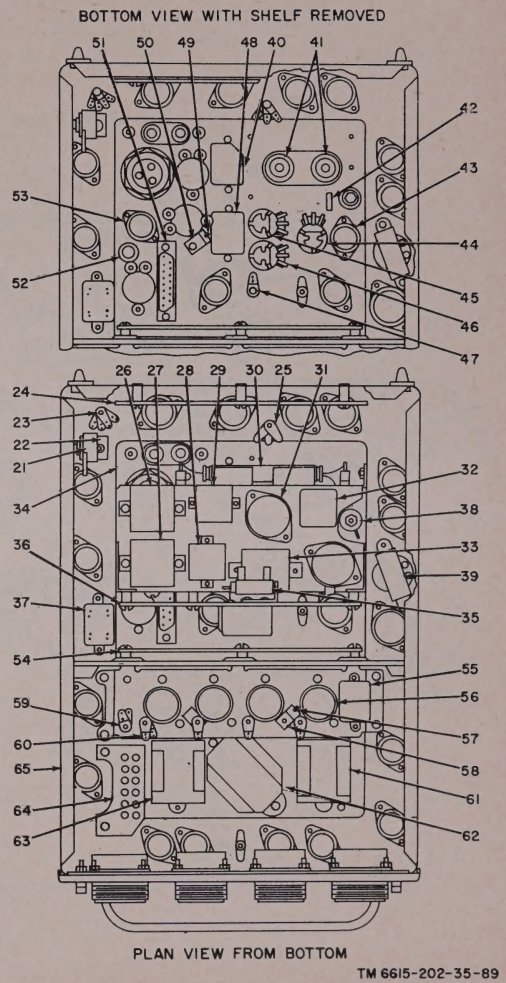


TM 6615-202-35-34

1 Sleeve
2 Grommet
3 Shock mount assembly
4 Shaft
5 Ring
6 Knurled nut assembly
7 Adjustment box cover assembly
8 Dust cover assembly
9 Amplifier assembly (pitch)
10 Captive screw
11 Amplifier assembly (altitude)
12 Multiple-channel amplifier assembly
13 Amplifier assembly (yaw)
14 Twelve-signal adjustment assembly
15 Clamp
16 Five-signal adjustment assembly
17 Vertical gyro assembly
18 Mounting plate
19 Bracket
20 Screw
21 Nut
22 Yaw synchronizer assembly
23 Nut
24 Main chassis assembly
25 Roll servo amplifier assembly

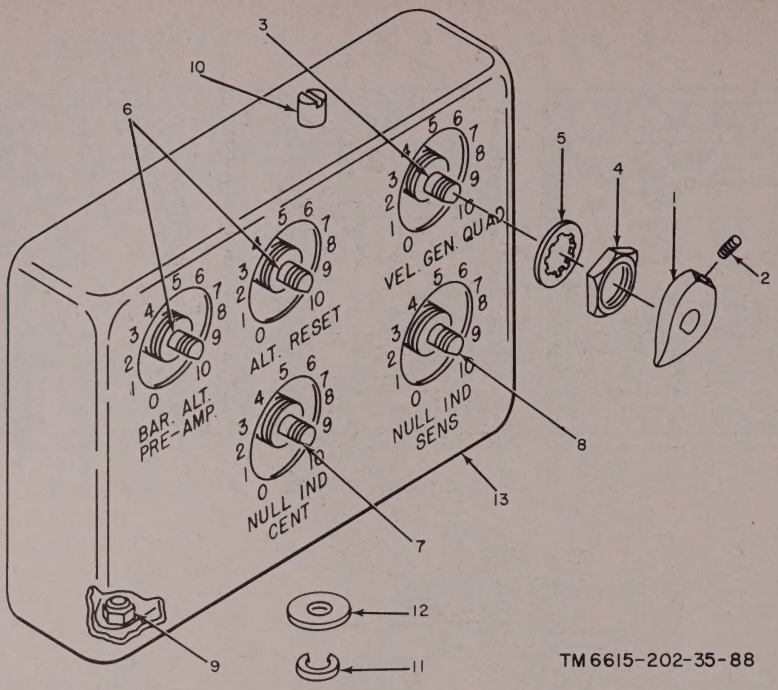
Figure 51. Control gyro and amplifier, plug-in assemblies, disassembly diagram.





1 Electron tube (V1)
2 Electron tube (V2, V3)
3 Electron tube (V4)
4 Relay (K6, K7)
5 Capacitor (C14)
6 Capacitor (C18A, C18B)
7 Thermal relay (K9)
8 Potentiometer (R46, R48)
9 Bracket assembly
10 Loop clamp
11 Relay (K1)
12 Connector (J4)
13 Connector (J3)
14 Connector (J2)
15 Connector (J1)
16 Socket (J6 through J19)
17 Amplifier chassis handle
18 Shock mount clip
19 Cover assembly
20 Screw
21 Potentiometer (R34)
22 Bracket assembly
23 Soldering lug
24 Terminal board (TB2)
25 Soldering lug
26 Transformer (T10)
27 Transformer (T11)
28 Transformer (T2)
29 Transformer (T3)
30 Capacitor (C8)
31 Rotary relay (K10, K11)
32 Armature relay (K8)
33 Transformer (T12)
34 Shelf assembly
35 Resistor (R38)
36 Terminal board (TB4)
37 Transformer (T1)
38 Resistor (R50)
39 Filter choke (L1)
40 Transformer (T9)
41 Socket assembly (J22, J23)
42 Resistor (R49)
43 Socket (XV4)
44 Potentiometer (R41)
45 Potentiometer (R17)
46 Potentiometer (R27)
47 Soldering lug
48 Transformer (T8)
49 Germanium crystal rectifier (CR 131)
50 Bracket and plate assembly
51 Connector (J5)
52 Rubber grommet
53 Socket (XK9)
54 Terminal board (TB1)
55 Transformer (T9)
56 Sealed relay (K2, K3, K4, K5)
57 Silicone diode (CR11, C312)
58 Bracket and plate assembly
59 Soldering lug
60 Bracket assembly
61 Transformer (T7)
62 Transformer (T6)
63 Transformer (T4)
64 Terminal board assembly (TB3)
65 Riveted chassis
66 Screw
67 Channel (servo amplifier assembly) clamping screw

Figure 52. Control gyro and amplifier, main chassis, disassembly diagram.



1 Knob
2 Set screw
3 Potentiometer (R603)
4 Nut
5 Lockwasher
6 Potentiometer (R605)
7 Potentiometer (R602)
8 Potentiometer (R601)
9 Screw and nut
10 Locking screw
11 Retainer ring
12 Flat washer
13 Welded chassis assembly

Figure 53. Five-signal adjustment assembly, disassembly diagram.

(3) Slide the main chassis assembly (24) into the dust cover assembly (8) and secure the dust cover with the four Dzus fasteners.

(4) Install the control gyro and amplifier on the shock mount assembly (par. 38*b*).

51. Replacement of Vertical Gyro Assembly, Control Gyro and Amplifier

(figs. 51, 53, and 54)

a. Removal.

(1) Remove the control gyro and amplifier from the shock mount assembly (par. 38*a*).

(2) Loosen the two Dzus fasteners on the rear of the dust cover assembly (8, fig. 51) and the two Dzus fasteners on the front panel of the main chassis assembly (24). Remove the dust cover assembly.

(3) Loosen the clamping screw (10) and remove the pitch servo amplifier (9).

(4) Remove the adjustment box cover assembly (7).

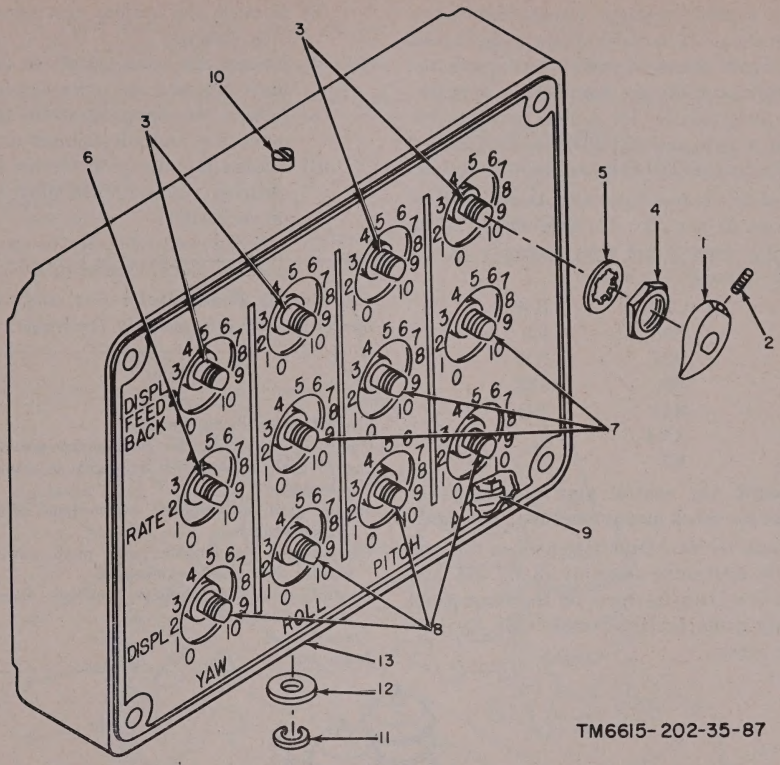
(5) Loosen the locking screw (10, fig. 54) and remove the 12-signal adjustment assembly.

(6) Remove clamp (15, fig. 51) and disconnect the vertical gyro assembly connector plug (not shown).

(7) Loosen the locking screw (10, fig. 53) and remove the five-signal adjustment assembly (16, fig. 51).

(8) Remove the three screws and nuts and remove mounting plate (18).

(9) Remove the vertical gyro assembly (17) from the main chassis assembly (24).



1 Knob
2 Set screw
3 Potentiometer (R503, R506, R509, and R512)
4 Nut
5 Lockwasher
6 Potentiometer (R502)
7 Potentiometer (R505, R508, and R511)
8 Potentiometer (R501, R504, R507, and R510)
9 Connector (P501, P502, P503, and P504)
10 Locking screw
11 Retainer ring
12 Flat washer
13 Welded chassis assembly

Figure 54. Twelve-signal adjustment assembly, disassembly diagram.

b. Replacement.

(1) Place the vertical gyro assembly (17, fig. 51) on the main chassis assembly (24), and install the mounting plate (18).

(2) Install the five-signal adjustment assembly (16) and secure it with the locking screw (10, fig. 53).

(3) Install the clamp (15, fig. 51) and connect the vertical gyro connector plug (not shown).

(4) Install the 12-signal adjustment assembly (14) and secure it with locking screw (10, fig. 54).

(5) Install the pitch servo amplifier (9, fig. 51) and secure it with screw (10).

(6) Install the adjustment box cover assembly (7).

(7) Slide the main chassis assembly (24) into the dust cover assembly (8), and secure the dust cover with the four Dzus fasteners.

(8) Install the control gyro and amplifier on the shock mount assembly (par. 38*b*).

52. Replacement of Parts for Control Panel, Control Gyro and Amplifier, and Motor Box

a. General. Parts contained on the control panel and the motor box are readily accessible and can be easily replaced. Parts mounted on the subassemblies and main chassis of the control gyro and

amplifier are readily accessible except those parts located under the shelf assembly on the main chassis (fig. 30). To gain access to any of these parts, remove the shelf assembly as described in *b* below. Disassembly diagrams for the control panel, motor box, and control gyro and amplifier are included for parts identification and listed in the chart in *c* below.

b. Removal of Control Gyro and Amplifier Shelf Assembly (figs. 51 and 52). To gain access to the following parts, remove the shelf assembly as described in (1) through (7) below:

K1	CR12	R49
XK9	J20	R5
C14	R27	R17
T9	J21	J22
T7	R41	J23
J5	XV4	
K6	K7	

(1) Remove the control gyro and amplifier from the shock mount assembly (par. 38*a*).

(2) Loosen the two Dzus fasteners on the rear of the dust cover assembly (8, fig. 51), and the two Dzus fasteners on the front panel of the main chassis assembly (24). Remove the cover.

(3) Remove the bottom dust cover assembly (not shown).

(4) Loosen the clamping screw (10) and remove the altitude servo amplifier.

(5) Loosen the clamping screw (10) and remove the multiple-channel amplifier.

(6) Loosen the clamping screws (66, fig. 52) securing the shelf assembly (two screws on each side).

(7) Lift the shelf assembly to one side to expose the parts mounted on the main chassis.

c. Control Panel, Motor Box, and Control Gyro and Amplifier Disassembly Diagrams.

Item	Fig. No.
Control gyro and amplifier	51
Control gyro and amplifier, main chassis assembly	52
Control gyro and amplifier, five-signal adjustment assembly	53
Control gyro and amplifier, twelve-signal adjustment assembly	54
Control gyro and amplifier, roll, pitch, yaw, or altitude servo amplifier assembly	55
Control gyro and amplifier, multiple channel amplifier assembly	56
Control panel	57
Motor box	58

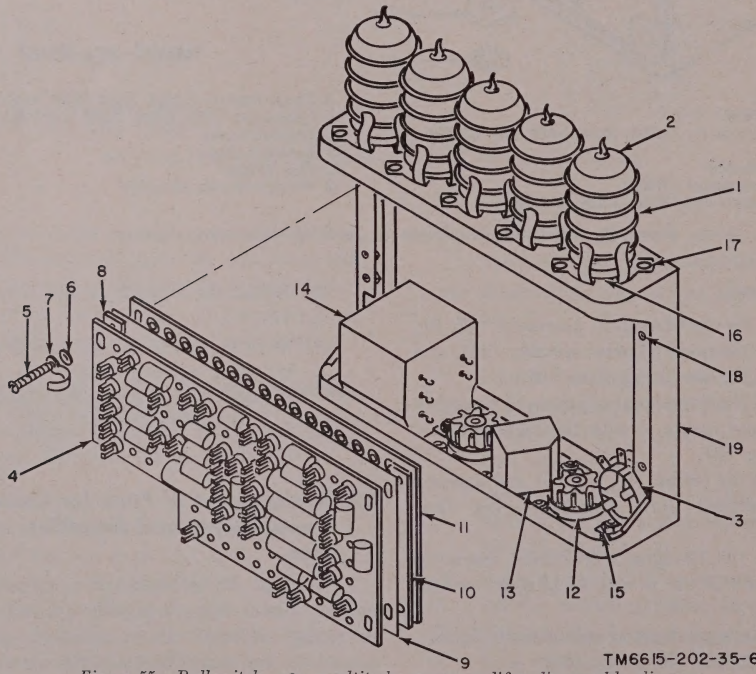
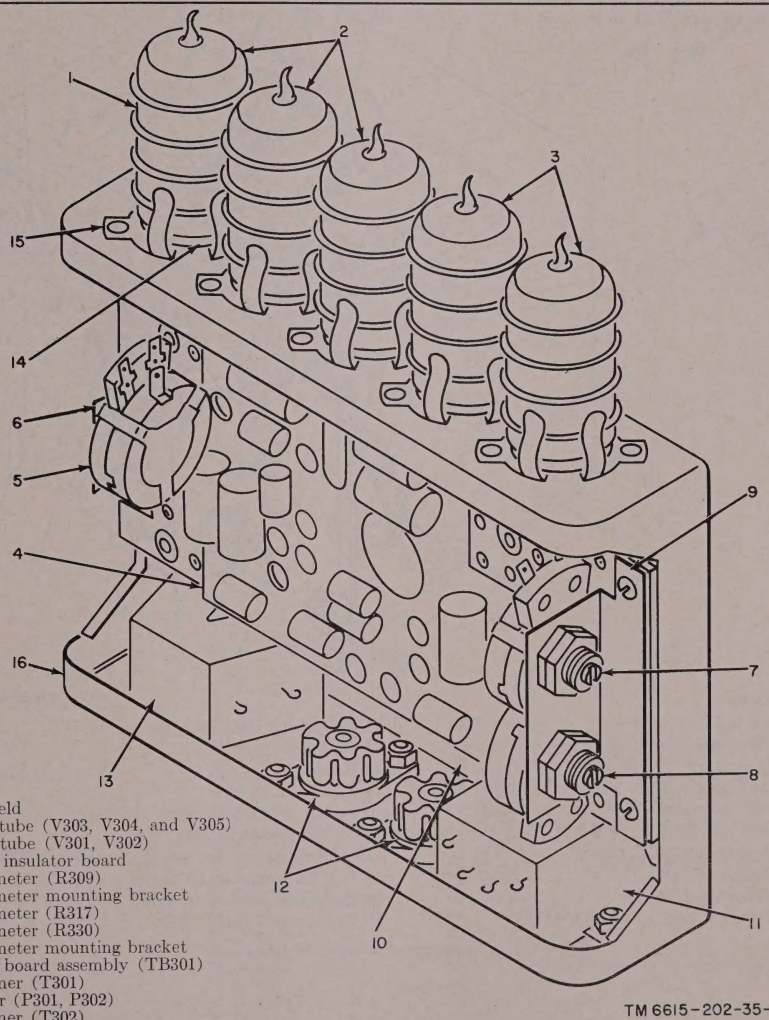


Figure 55. Roll, pitch, yaw or altitude servo amplifier disassembly diagram.

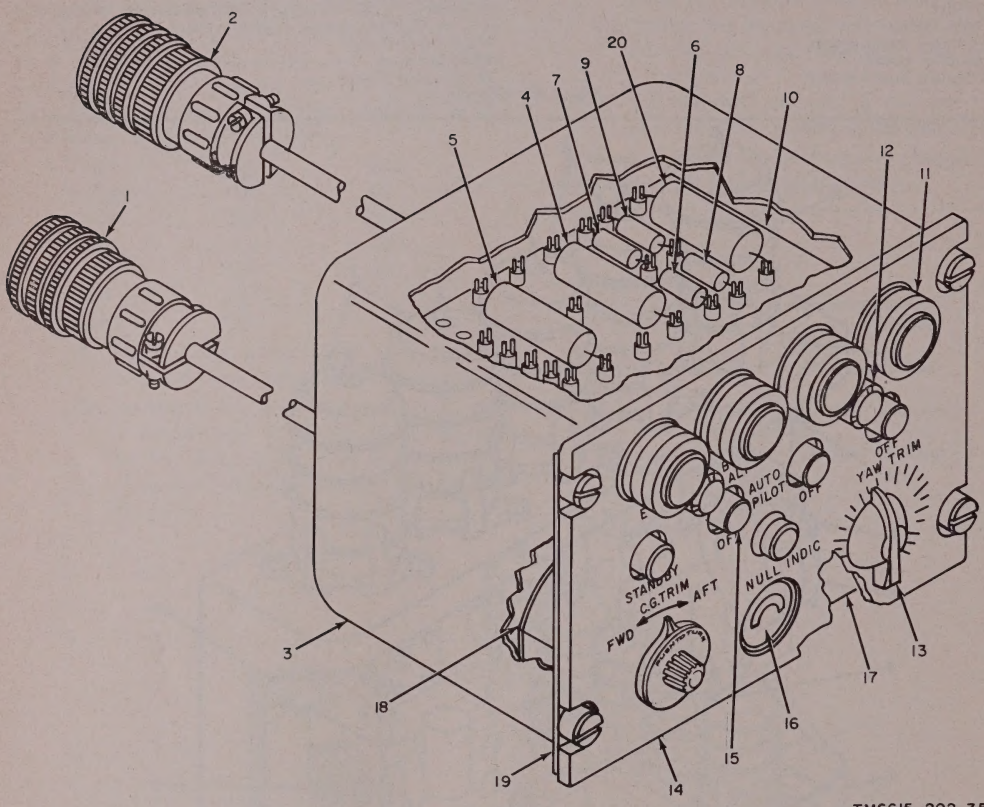
1 Tube shield
2 Electron tube (V201 through V205) pitch, roll, and altitude or (V401 through V405) yaw
3 Potentiometer (R226) pitch, roll, and altitude or (R426) yaw
4 Terminal board assembly (TB201) pitch, roll, and altitude or (TB401) yaw
5 Screw
6 Washer
7 Cable clamp
8 Terminal board spacer
9 Insulator board
10 Terminal board spacer
11 Terminal board assembly (TB202)
12 Connector (P201, P202) pitch, roll, and altitude, or (P401, P402) yaw
13 Transformer (T202) pitch, roll, and altitude or (T402) yaw
14 Transformer (T201), pitch, roll, and altitude or (T401) yaw
15 Potentiometer bracket
16 Socket (XV201 through XV205) pitch, roll, and altitude or (XV401 through XV405) yaw
17 Shield base clip
18 Clinch nut
19 Stenciled chassis

Figure 55—Continued.



1 Tube shield
2 Electron tube (V303, V304, and V305)
3 Electron tube (V301, V302)
4 Stenciled insulator board
5 Potentiometer (R309)
6 Potentiometer mounting bracket
7 Potentiometer (R317)
8 Potentiometer (R330)
9 Potentiometer mounting bracket
10 Terminal board assembly (TB301)
11 Transformer (T301)
12 Connector (P301, P302)
13 Transformer (T302)
14 Socket (XV301 through XV305)
15 Shield base clip
16 Stenciled chassis

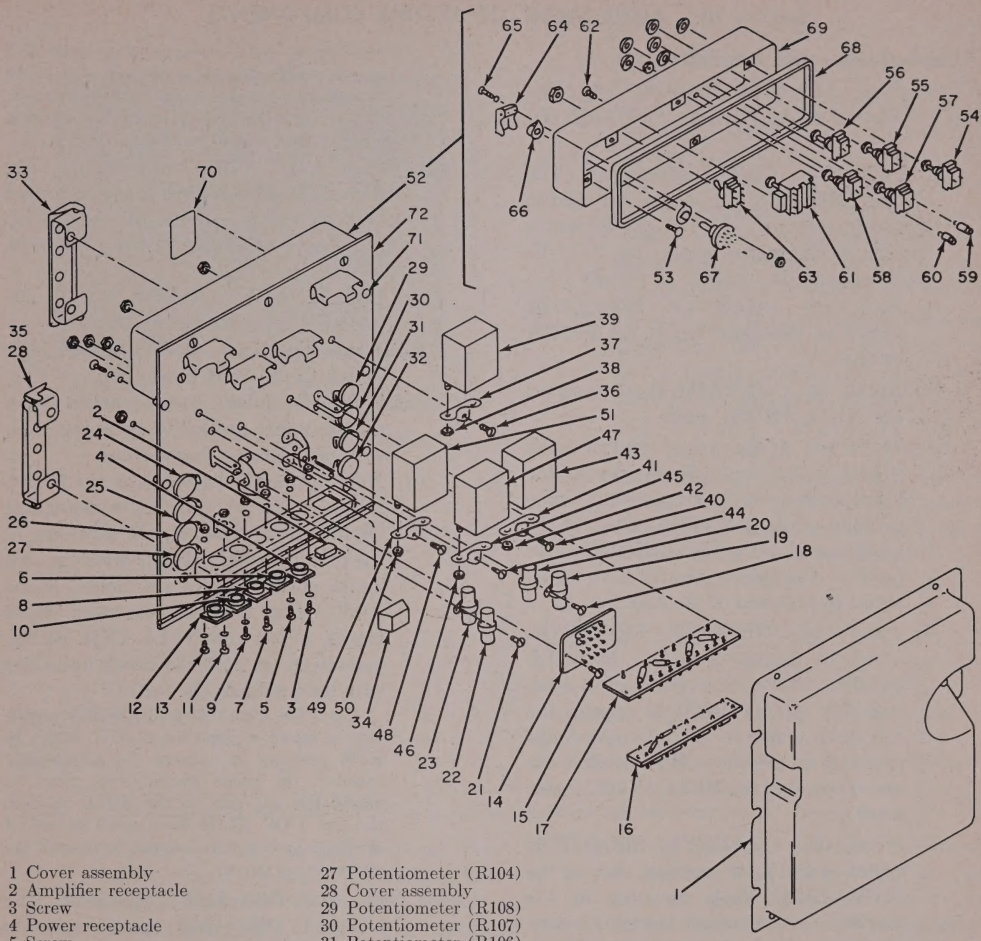
Figure 56. Multiple-channel amplifier disassembly diagram.



TM6615-202-35-8

1 Connector (J6)
2 Connector (J5)
3 Dust cover
4 Capacitor (C102)
5 Capacitor (C101)
6 Resistor (R103)
7 Resistor (R104)
8 Resistor (R105)
9 Resistor (R106)
10 Terminal board (TB101)
11 Switch and light assembly
12 Cover and lamp
13 Knob
14 Panel
15 Switch (S105, S106, S107, and S108)
16 Null indicator (M101)
17 Differential synchro and gear assembly (B101)
18 Learsyn assembly (B102)
19 Panel and bracket assembly
20 Capacitor (C103)

Figure 57. Control panel, disassembly diagram.



1 Cover assembly
2 Amplifier receptacle
3 Screw
4 Power receptacle
5 Screw
6 Yaw receptacle
7 Screw
8 Roll receptacle
9 Screw
10 Altitude receptable
11 Screw
12 Pitch receptacle
13 Screw
14 Terminal board assembly (TB103)
15 Screw
16 Resistor board assembly (TB104)
17 Capacitor board assembly (TB101)
18 Screw
19 Capacitor
20 Capacitor
21 Screw
22 Capacitor
23 Capacitor
24 Potentiometer (R101)
25 Potentiometer (R102)
26 Potentiometer (R103)
27 Potentiometer (R104)
28 Cover assembly
29 Potentiometer (R108)
30 Potentiometer (R107)
31 Potentiometer (R106)
32 Potentiometer (R105)
33 Cover assembly
34 Transformer (T101)
35 Screw
36 Screw
37 Bracket
38 Nut
39 Magnetic amplifier
40 Screw
41 Bracket
42 Nut
43 Magnetic amplifier
44 Screw
45 Bracket
46 Nut
47 Magnetic amplifier
48 Screw
49 Bracket
50 Nut
51 Magnetic amplifier
52 Motor box panel assembly
53 Screw
54 CHANNEL DISENGAGE-PITCH switch (S4)
55 CHANNEL DISENGAGE-ALT. switch (S5)
56 CHANNEL DISENGAGE-ROLL switch (S6)
57 CHANNEL DISENGAGE-YAW switch (S7)
58 CHANNEL DISENGAGE-GOV. switch (S8)
59 MOTOR POSITION-MOTOR INPUT switch (S2)
60 MOTOR VOLTAGE TEST jack
61 OVERRIDE CHECK switch (S3)
62 Screw
63 Switch
64 Guard assembly
65 Screw
66 Knob
67 CHANNEL SELECTOR switch (S1)
68 Edging
69 Panel assembly
70 Name plate
71 Stud
72 Panel assembly

Figure 58. Motor box, disassembly diagram.

53. Control Gyro and Amplifier

a. Five-signal Adjustment Assembly (fig. 59). Adjust the controls as described in (1) through (5) below.

(1) *NULL IND. CENT. adjustment.* The NULL IND. CENT. adjustment is used to properly center the NULL INDIC meter needle on the control panel (fig. 57). To center the needle, proceed as follows:

(*a*) Place the CHANNEL SELECTOR switch on the motor box to the PITCH position.

(*b*) Rotate the C G TRIM knob to center the NULL INDIC needle.

(*c*) Move the pilot's cyclic control stick smoothly fore and aft to operate the pitch servo motor to its end stops (indicated by an audible click). Observe the arc of travel of the NULL INDIC meter needle. The needle should have equal travel to each end of the dial.

(*d*) Place the CHANNEL SELECTOR switch on the motor box to the ROLL position. Move the cyclic control stick smoothly left and right to operate the roll servo motor to its end stops (indicated by an audible click). Observe the arc of travel of the NULL INDIC meter needle.

(*e*) Place the CHANNEL SELECTOR switch in the YAW position. Rotate the YAW TRIM knob smoothly in the clockwise and counterclockwise direction to operate the yaw servo motor to its end stops (indicated by an audible click). Observe the arc of travel of the NULL INDIC meter needle.

(*f*) If the arc of travel of the NULL INDIC meter needle is not properly centered in *all* modes ((*a*) through (*e*) above), center the needle by adjusting the NULL IND. CENT. potentiometer.

Notes.

1. If the arc of travel of the NULL INDIC meter needle is not properly centered in one mode, but is centered in all other modes, the servo motor for that mode is probably defective.

2. The setting of the NULL IND. CENT. potentiometer may change during warmup, reaching its steady state operating point after approximately 45 minutes. Because of this slow drift, there is no need to wait for final warmup; if there is a discrepancy in needle centering, another check should be made.

(2) *NULL IND. SENS. adjustment.* The NULL IND. SENS. potentiometer is used to adjust the sensitivity of the NULL INDIC meter to control the range of needle travel.

(*a*) Perform the NULL IND. CENT. adjustment described in (1) above.

(*b*) Place the CHANNEL SELECTOR switch to the PITCH position.

(*c*) Move the pilot's cyclic control stick smoothly fore and aft to cause the pitch servo motor to hit its end stops.

(*d*) Note the needle deflection on the NULL INDIC meter when the servo motor hits its end stops. The extreme positions of the needle should coincide with the two marks on the face of the meter. If the needle does not coincide with these marks, adjust the NULL IND. SENS. potentiometer until the needle coincides with the marks on the meter.

Note. The CHANNEL SELECTOR switch may be placed in either the PITCH, ROLL, or YAW positions to perform this adjustment; however, the cyclic control stick must be moved left and right in the ROLL position, and the YAW TRIM knob must be moved clockwise and counterclockwise to operate the related servo motor.

(3) *BAR. ALT. PRE-AMP. adjustment.* The BAR. ALT. PRE-AMP. potentiometer is used to adjust the gain of the barometric altitude signal applied to the altitude servo amplifier. Set this control to its full clockwise position.

(4) *VEL. GEN. QUAD adjustment.* The VEL. GEN. QUAD potentiometer is used to adjust the balance of the quadrature nulling circuit to properly null unwanted quadrature voltages in the yaw channel. Set this potentiometer to position 5.

(5) *ALT. RE-SET adjustment.* This adjustment is not used in Autopilot AN/ASN–23.

b. Twelve-signal Adjustment Assembly (fig. 60).

(1) *General.* The twelve-signal adjustment assembly contains a DISPL FEEDBACK,

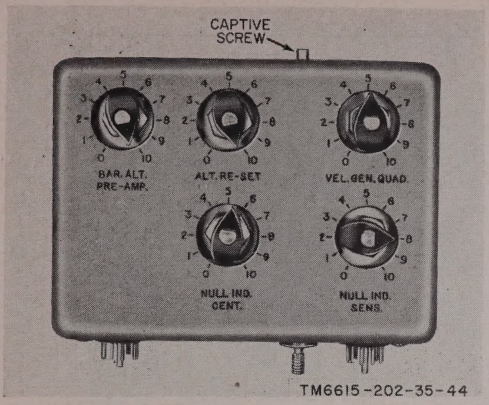


Figure 59. Five-signal adjustment assembly, adjustment controls.

RATE, AND DISPL potentiometer for each of the four modes. The DISPL FEEDBACK potentiometers are used to adjust the amplitude of the transducer feedback signal to give proper nulling of the displacement signal in each channel. The RATE potentiometers are used to adjust the amplitude of the rate signal in each channel so as to properly reflect the rate of displacement. The DISPL potentiometers are used to adjust the gain of the displacement preamplifiers to give proper signal strength to operate the servo motors.

(2) *Channel gain settings.* Most twelve-signal adjustment assemblies have been modified so that the settings of the individual controls are indicated by white and red dots. The proper settings for these controls are listed in the chart below. On twelve-signal adjustment assemblies that have not been so marked, a calibration procedure for placing the white and red dots is given in the charts in (3) below.

Potentiometer	Channel gain setting			
	YAW	ROLL	PITCH	ALTITUDE
DISPL FEEDBACK	red	white	red	white
RATE	red	red	red	white
DISPL	red	white	red	white

Note. The gain settings in the above chart pertain to Army Helicopter H-34A autopilot installations only.

(3) *Calibration of channel gain settings.* For those 12-signal adjustment assemblies that do not contain the white and red markings, refer to the chart in (*a*) below to determine the point at which the *white* markings (dots) should be placed. Refer to the chart in (*b*) below to determine the point at which the *red* markings should be placed. After the assembly has been marked, refer to the chart in (2) above to properly set each control.

(*a*) *Calibration of white markings.*

Potentiometer	Channel gain setting			
	YAW	ROLL	PITCH	ALTITUDE
DISPL FEEDBACK (resistance between pins 5 and 7).	80.6% of resistance between pins 5 and 6 of P501.	80% of resistance between pins 5 and 6 of P502.	56% of resistance between pins 5 and 6 of P503.	100% of resistance between pins 5 and 6 of P504.
RATE (resistance between pins 3 and 4).	93% of resistance between pins 4 and 8 of P501.	68% of resistance between pins 4 and 8 of P502.	48% of resistance between pins 4 and 8 of P503.	56.7% of resistance between pins 4 and 8 of P504.
DISPL (resistance between pins 1 and 2).	9,100 ohms between pins 1 and 2 of P501.	23,700 ohms between pins 1 and 2 of P502.	16,200 ohms between pins 1 and 2 of P503.	16,090 ohms between pins 1 and 2 of P504.

(*b*) *Calibration of red markings.*

Potentiometer	Channel gain setting			
	YAW	ROLL	PITCH	ALTITUDE
DISPL FEEDBACK	Minus 3 divisions (or as much as possible) from white mark.	No red mark.	Minus 0.4 divisions from white mark.	No red mark.
RATE	Resistance between pins 3 and 4 of P501 86% of resistance between pins 4 and 8.	Minus 1 division from white mark.	Minus 2.5 divisions from white mark.	Fully counterclockwise.
DISPL	Plus 0.5 division from white mark.	No red mark.	Minus 2 divisions (or as much as possible) from white mark.	No red mark.

c. Time Delay Relay K9 (main chassis). Time delay relay K9 (fig. 29) prevents the autopilot from being engaged before the gyro in the vertical gyro assembly has erected and stabilized by providing a delay of 150 ±30 seconds. Adjust the relay as described in (1) through (8) below.

(1) Remove the control gyro and amplifier from the shock mount assembly (par. 38*a*).

(2) Loosen the two Dzus fasteners on the rear of the dust cover assembly and the two Dzus fasteners on the front panel of the main chassis assembly. Remove the cover.

(3) Start the helicopter engine or connect an auxiliary power unit to the helicopter.

(4) Engage the AUTO STABE circuit breaker on the overhead control panel (note the time).

(5) Wait approximately 1 minute and then momentarily press the ENG switch on the control panel. The green lamp inside the switch should *not* light. Repeatedly press and release the ENG switch until the ENG lamp lights (indicating autopilot engagement). Note the delay from the time the AUTO STABE circuit breaker was set ((4) above) to the time the lamp in the ENG switch lights.

(6) If the light does not light within the specified time (150 ±30 seconds) adjust time delay relay K9 by rotating the adjusting screw located at the top of the relay.

Note. Turn the adjusting screw *in* to shorten the time delay, and *out* to lengthen the time delay.

(7) Press the AUTO STABE RELEASE switch on the pilot's or copilot's cyclic control stick to disengage the autopilot.

(8) Wait approximately 2 minutes for the relay element to cool and repeat (4) through (6) above until the correct time delay has been obtained.

d. Roll Integrator Adjustments (Multiple Channel Amplifier Assembly).

(1) *Adjustments.* The roll integrator circuit of the multiple channel amplifier requires a null adjustment and a gain adjustment provided by potentiometers R330 and R309, respectively (fig. 33). Procedures for performing these adjustments will be provided when the special test equipment and test fixtures required become available.

Note. Multiple channel amplifier assemblies received directly from the manufacturer should be preadjusted.

(2) *Selection of capacitor C305.* The value of capacitor C305 must be either 0.001 or 0.0022 microfarad ±5 percent at 600 VDC. The value of capacitor C305 is determined through the use of special test equipment that is not available at this time. If it is necessary to replace capacitor C305, replace it with a serviceable capacitor of the same value.

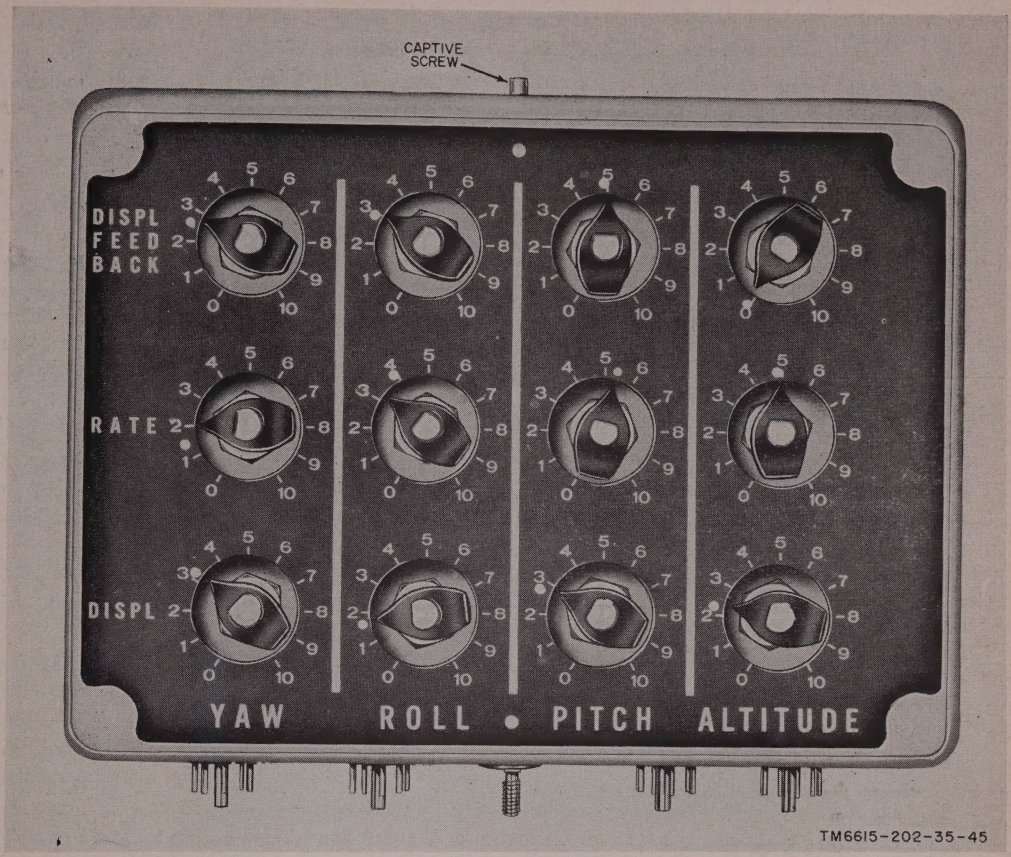


Figure 60. Twelve-signal adjustment assembly, adjustment controls.

e. Pitch and Roll Bridge Adjustments (Main Chassis). Potentiometers R34 (fig. 32) and R41 (fig. 29) are provided to adjust the output of the vertical gyro assembly. Procedures for performing the pitch and roll bridge adjustments will be provided when the special test equipment and test fixtures required become available.

f. Servo Amplifier Assembly Gain Adjustment (Pitch, Roll, Yaw, and Altitude Servo Amplifiers).

(1) *Gain adjustments.* Potentiometers R226 on the pitch, roll, and altitude servo amplifiers (figs. 32 and 33) and R426 on the yaw servo amplifier (fig. 31) are provided to control servo amplifier gain. No changes in adjustment should be made on installed equipment. Procedures for performing these gain adjustments will be provided when the special test equipments and test fixtures required become available.

Note. Servo amplifier assemblies received direct from the manufacturer should be preadjusted.

(2) *Selection of matched resistors.* Follow the procedure given below to select a replacement for a defective matched resistor.

(*a*) All matched resistors are ±5 percent of the value in the chart in (*c*) below.

(*b*) The replacement resistor must be within ±2 percent of the value of the resistor with which it is to be matched.

(*c*) The following chart lists the matched resistors and gives the value of each resistor and its location:

Matched Resistors	Value	Location
R207 and R208	100K	Pitch, Roll, and Altitude Servo Amplifiers
R209 and R210	270K	
R211 and R212	510K	
R216 and R217	100K	
R220 and R221	620K	
R407 and R408	100K	
R409 and R410	270K	Yaw Servo Amplifier
R411 and R412	510K	
R416 and R417	100K	
R420 and R421	220K	
R313 and R314	470K	
		Multiplier Channel Amplifier

54. Motor Box Assembly
(fig. 61)

The F. U. NULL potentiometers and the TACH. GEN. potentiometers are provided on the motor box for adjustments of the null and excitation voltage to the altitude, roll, pitch, and yaw servo motors. Adjust the potentiometers as described in *a* through *j* below.

a. Start the helicopter engine.

b. Engage the AUTO STABE circuit breaker.

c. Wait approximately 2½ minutes and press the ENG button on the control panel.

d. Place the autopilot system in standby condition by pressing the STANDBY button on the control panel.

e. Place the CHANNEL SELECTOR switch on the motor box to the PITCH position.

f. Monitor the NULL INDIC meter needle and adjust the F. U. NULL -P potentiometer for a center reading on the NULL INDIC meter. The potentiometer setting should be not less than 4 and not greater than 6.

g. Monitor the NULL INDIC meter needle and adjust the TACH. GEN. -P potentiometer to remove any servo motor oscillation as indicated by NULL INDIC meter needle. The potentiometer setting for each channel should be adjusted to a gain setting just high enough to remove oscillation, but not exceeding 4 on the TACH. GEN. -P, -R, and -Y potentiometers and not exceeding 3.5 on the TACH. GEN. -A potentiometer.

h. Repeat procedures in *e* through *g* above with the CHANNEL SELECTOR switch in the ALT, ROLL, and YAW positions and using the appropriate F. U. NULL and TACH. GEN. A, R, and Y potentiometers.

i. Disengage the autopilot system by pressing the AUTO STABE RELEASE switch on the pilot's or copilot's cyclic control stick.

j. Turn off the helicopter engine.

55. Time Delay Relay (Motor Release)
(fig. 50)

After the autopilot is disengaged, the time delay relay provides a 2-second delay before power is removed from the servo motors. This time delay allows the servo motors to electrically null or come to rest. Adjust the time delay relay as described below.

a. Start the helicopter engine.

b. Engage the AUTO STABE circuit breaker.

c. After approximately 2½ minutes, engage the autopilot by pressing the ENG button on the control panel.

d. Arrange a multimeter to measure +28 volts dc. Connect the multimeter across pins 2 and 3 of the time delay relay.

e. Disengage the autopilot by pressing the AUTO STABE RELEASE switch on the pilot's or copilot's cyclic control stick.

f. The reading on the multimeter should drop to zero voltage 2 seconds after the autopilot system has been disengaged.

g. If the voltage does not drop to zero 2 seconds after depressing the AUTO STABE RELEASE switch, adjust the relay by rotating the screw at the top of the relay. Turn the adjusting screw *in* to shorten the time delay, and *out* to lengthen the time delay.

h. Repeat the procedures given in *c* through *g* above until the correct time delay has been obtained.

56. Control Stick Canceller Assembly
(fig. 48)

The following adjustment alines the cancellers to properly cancel out roll and pitch displacement signals which develop during a manual change in flight attitude.

a. Roll Canceller Adjustment.

Note. To perform a periodic check only of the roll canceller, omit steps (3) and (6) through (12) below.

(1) Place the CHANNEL SELECTOR switch in the ROLL position.

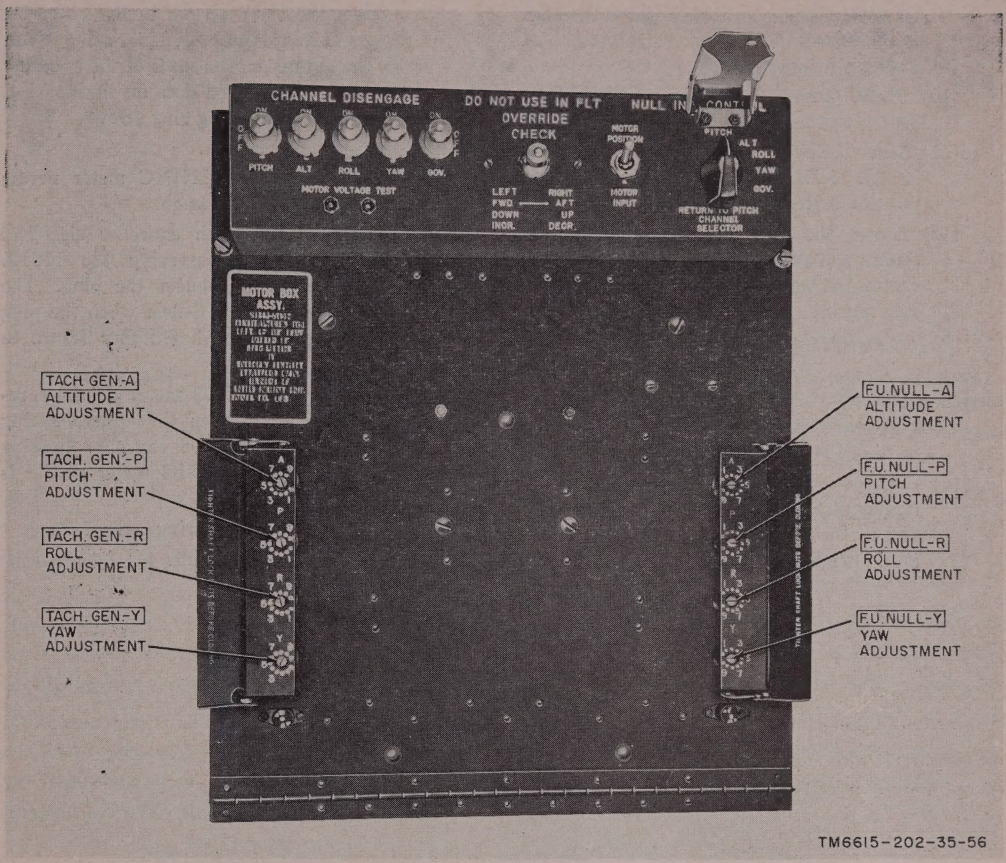


Figure 61. Motor box assembly, TACH. GEN. and F. U. NULL potentiometers.

(2) Center the cyclic control stick and install rigging pins in the cyclic control stick yoke and in the bell cranks, so that the sticks are in neutral position.

(3) Loosen the three screws in the adjusting ring and rotate the canceller housing to line up the red dot on the shaft of the canceller between the two red dots on the housing.

(4) Engage the autopilot.

(5) Loosen the two knurled nuts that secure the control gyro and amplifier to the shock-mount. Raise the front (outboard end) of the control gyro and amplifier to introduce a 1° left roll with respect to the true vertical. Use a protractor resting solidly on the flat surface of the control gyro and amplifier cover to measure the angle. The NULL INDIC meter needle should be centered.

(6) If the needle is not centered, rotate the housing of the roll canceller to center the needle.

(7) Tighten the adjusting ring screws.

(8) Secure the control gyro and amplifier in its normal position and remove the rigging pins.

Note. If the pilot reports excessive lateral jump when engaging or disengaging the autopilot, find out from the pilot the exact position of the NULL INDIC meter needle when the autopilot is engaged and the CHANNEL SELECTOR switch is set to the ROLL position during hands

off flight. Readjust the roll canceller as described in (9) through (12) below.

(9) Engage the autopilot.

(10) Place the CHANNEL SELECTOR switch to the ROLL position.

(11) Move the cyclic control stick to place the NULL INDIC meter needle in the exact position stated by the pilot.

(12) Loosen the roll canceller adjusting ring screws and rotate the canceller housing to center the needle. Tighten the adjusting ring screws.

b. Pitch Canceller Adjustment.

Note. To perform a periodic check only of the pitch canceller omit step (3) and steps (7) through (9) below.

(1) Place the CHANNEL SELECTOR switch in the PITCH position.

(2) Center the cyclic control stick and install rigging pins in the cyclic control stick yoke and in the bell cranks, so that the sticks are in neutral position.

(3) Loosen the three screws in the adjusting ring and rotate the canceller housing to line up the red dot on the shaft of the canceller between the two red dots on the housing. Tighten the adjusting ring screws.

(4) Engage the autopilot.

(5) Center the NULL INDIC meter needle with the C G TRIM knob.

(6) Disconnect the pitch canceller electrical plug and, while observing the NULL INDIC meter, reconnect the plug. The meter needle should deflect when the plug is reconnected and should then return to center.

(7) If the NULL INDIC meter does not return to center, loosen the adjusting ring screws and rotate the canceller housing until the NULL INDIC meter needle is centered.

(8) Tighten the adjusting ring screws.

(9) Remove the rigging pins.

CHAPTER 4

SYSTEM TESTS

57. Servo Motor Checks

The servo motor checks are the motor phasing and damping check, the motor bind check (*b* below), and the motor dead band check (*c* below). Perform the following servo motor checks with the autopilot in standby condition.

a. Servo Motor Phasing and Damping Check. Incorrect phasing of a servo motor will cause it to rotate in the wrong direction for the associated displacement signal. Improper damping will cause it to oscillate. Check motor phasing and damping by following the procedures in (1) through (4) below.

***Caution:* Be sure that the F. U. NULL potentiometers on the motor box panel are all set within the limits of 4 to 6 before proceeding with directions in (1) through (4) below.**

(1) Place the CHANNEL SELECTOR switch on the motor box panel to the PITCH position.

(2) Move the OVERRIDE CHECK switch to the LEFT FWD DOWN position, normal (or center) position, and to the RIGHT AFT UP position in that order. Check to see that the NULL INDIC meter needle and the servo motor power piston respond as indicated in the chart in (5) below.

(3) Repeat procedures in (1) and (2) above with the CHANNEL SELECTOR switch in the ALT, ROLL, and YAW position.

(4) Return the OVERRIDE CHECK switch to normal (or center) position after completing procedures given in (1) through (3) above.

(5) Chart:

CHANNEL SELECTOR switch position	OVERRIDE CHECK switch position		
	LEFT FWD DOWN	Normal	RIGHT AFT UP
PITCH	NULL INDIC needle left. Sero motor power piston aft.	NULL INDIC needle returns to center and does not oscillate (all modes).	NULL INDIC needle right. Servo motor power piston forward.
ALT	NULL INDIC needle left. Servo motor power piston aft.		NULL INDIC needle right. Servo motor power piston forward.
ROLL	NULL INDIC needle left. Servo motor power piston aft.	Servo motor power piston returns to null (all modes).	NULL INDIC needle right. Servo motor power piston forward.
YAW	NULL INDIC needle left. Servo motor power piston forward.		NULL INDIC needle right. Servo motor power piston aft.

b. Servo Motor Bind Check. A maximum steady 15-volt input on the control phase winding of a servo motor should start servo motor rotation. However, as the motors drive in either direction from their null (center) position toward a stop, intermittent voltages up to a maximum of 30 volts may be noted, and the steady voltage necessary to drive the motors the last fifth of their travel should increase to a maximum of 20 volts. The maximum voltage necessary to drive the motors back from a stop to the null position should not exceed 15 volts at any point of travel. In the motor bind check, the NULL INDIC meter is connected as a voltmeter across the control phase winding of the motor, and needle motion of about one needle width approximate 10 volts. As the motor rotates, the transducer feedback voltage will cancel out the input voltage. Motor bind, which prevents motor rotation, will cause motor input voltage to increase above the maximum limits specified, and the equipment will not operate satisfactorily. Check for motor bind as follows:

(1) Place the CHANNEL SELECTOR switch to the PITCH position.

(2) Hold the MOTOR POSITION—MOTOR INPUT switch in the MOTOR INPUT position.

(3) Apply an input voltage to the control windings of the servo motor by turning the F. U. NULL-P potentiometer on the motor box (fig. 61) smoothly and slowly in one direction and then in the opposite direction. Observe the NULL INDIC meter and note that there may be a small needle movement as the potentiometer is rotated. Check to see that this movement does not exceed two needle widths. Greater movement indicates excessive servo motor bind. When the servo motor reaches its end stop, the NULL INDIC meter needle should move at least ¼ half-travel when the potentiometer has been turned almost all the way in either direction.

(4) Release the MOTOR POSITION—MOTOR INPUT switch.

(5) Adjust the potentiometer to null the servomotor, as indicated by the NULL INDIC meter needle being centered. The potentiometer setting should read between 4 and 6.

(6) Repeat the procedures given in (2) through (5) above for the remaining servo motors with the CHANNEL SELECTOR switch set to ALT, ROLL, and YAW and adjust the F.U. NULL-A, F.U. NULL-R, and F.U. NULL-Y, potentiometers, respectively. Null each mode before proceeding to the next.

c. Servo Motor Dead Band Check. The dead band check is a check of the sensitivity of the auxiliary servo assembly response to servo motor rotation. The NULL INDIC meter indicates transducer voltage, which is a function of the amount of servo rotation, and thus reflects servo motor position. If the auxiliary servo assembly power piston for the mode being checked does not respond by the time the NULL INDIC meter needle has moved one needle width, excessive play in the mechanical linkage between the servo motor yoke assembly and the power piston is indicated. The excessive play is probably in the connection between the servo motor yoke and the differential link actuating the pilot valve in the servo unit assembly. Perform the servo motor dead band check as follows:

(1) Place the CHANNEL SELECTOR switch to the PITCH position.

(2) Place one hand on the pitch power piston to sense its motion and observe the NULL INDIC meter needle while turning the F.U. NULL-P potentiometer smoothly and slowly in one direction and then in the opposite direction. Check to see that the power piston moves when the needle deflects one needle width from the center, and that the power piston moves back and forth for plus or minus one needle width deflection.

(3) Adjust the potentiometer to null the servo motor as indicated by the NULL INDIC meter needle being centered. The potentiometer setting should read between 4 and 6.

(4) Repeat procedures given in (1) through (3) above with the CHANNEL SELECTOR switch set to the ALT, ROLL, and YAW positions, and adjusting the F.U. NULL-A, F.U. NULL R, and F. U. NULL-Y potentiometers, respectively. Null each channel before proceeding to the next.

58. Mode Engagement Check

The mode engagement check is used to determine whether or not the control circuits of the autopilot

are functioning properly. Perform the following checks with the autopilot in standby condition.

a. Press the ENG and then the BAR ALT switch on the control panel. Check to see that the light inside each switch comes on.

b. Press the BAR ALT OFF switch. Check to see that the BAR ALT light goes out. Press the STANDBY switch. Check to see that the ENG light goes out.

c. Repeat the procedures given in *a* above; then press the STANDBY switch and see that both the ENG and BAR ALT switch lights go out.

d. Press the ENG switch, then press the pilot's AUTO STAB. RELEASE switch on the cyclic control stick grip. See that the ENG switch light goes out. Repeat using the copilot's AUTO STAB. RELEASE switch.

e. Operate the CHANNEL SELECTOR switch to the PITCH position.

f. Press the ENG switch and then press the pilot's AUTO STAB. RELEASE switch. Rotate the pitch F.U. NULL-P potentiometer and check to see that the NULL INDIC meter needle does not move.

g. Press the ENG switch and then the STANDBY switch. Rotate the F.U. NULL-P potentiometer and check to see that the NULL INDIC meter needle moves.

h. Adjust the F.U. NULL-P potentiometer to null the servo motor as indicated by the NULL INDIC meter needle being centered. The potentiometer setting should indicate between 4 and 6.

i. Repeat *f* through *h* above using the copilot's AUTO STAB. RELEASE switch.

j. Press the ENG switch and rotate the C G TRIM knob in either direction until the NULL INDIC meter needle reaches one of its extreme positions. Press the pilot's or copilot's AUTO STAB. RELEASE switch and check to see that the needle deflects toward its center position and then stops within approximately 2½ seconds.

Note. Rotating the C G TRIM knob in a clockwise direction will cause the NULL INDIC meter needle to deflect to the left.

k. Rotate the C G TRIM knob back and forth and at the same time, press the ENG switch. Check to see that there is no more than a 1-second delay between the time the ENG switch is pressed and the NULL INDIC meter needle starts to follow the motion of the C G TRIM knob.

59. Engage Error Checks

The engage error checks determine whether or not the autopilot will engage without undue flight disturbance. Perform the following checks with the autopilot in standby condition.

a. Altitude Engage Error Check. The altitude engage error check determines whether the altitude mode will stabilize the helicopter within permissible limits of altitude manually established by the pilot. Check the altitude engage error as follows:

(1) Place the autopilot in the standby condition.

(2) Set the CHANNEL SELECTOR switch on the motor box panel to the ALT position.

(3) Press the ENG switch on the control panel and note the position of the NULL INDIC meter needle.

(4) Press the BAR ALT switch on the control panel and check to see that the NULL INDIC meter needle does not move more than ⅓ the distance, left or right, to the full half-travel mark on the indicator.

Note. The mechanical linkage in the altitude control may cause the altitude engage error to be variable. If the engage error seems excessive, repeat the check several times. If the error is persistently excessive, check the altitude input response (par. 60*d*).

(5) Press the STANDBY switch to return the autopilot to the standby condition.

b. Yaw Engage Error Check. The yaw mode is automatically placed in standby during manual turns, by depressing any one of the tail rotor pedal switches. During such turns, the turn motor in the yaw modes operates to null the turn displacement signal arising from the change in heading, so that the helicopter will stabilize on the new heading when the pedal is released. The yaw engage error check determines whether the turn system of the yaw mode is operating properly. Check the yaw engage error as follows:

(1) Set the CHANNEL SELECTOR switch on the motor box panel to the YAW position.

(2) Press the ENG switch on the control panel and rotate the YAW TRIM knob until the NULL INDIC meter needle moves to one side. Rotation of the YAW TRIM knob in a clockwise direction will cause the NULL INDIC meter needle to move to the right.

(3) Press and hold down any one of the four tail rotor pedal switches and see that the NULL INDIC meter needle returns to null (center) position.

(4) Try to make the needle move by rotating the YAW TRIM knob. The needle should remain centered.

(5) After 4 or 5 seconds, release the pedal slowly and check to see that the pedal switches do not stick in the actuated position. The needle should remain centered.

(6) Repeat procedures given in (2) through (5) above until all four of the pedal switches have been checked.

(7) Rotate the YAW TRIM knob to again displace the NULL INDIC meter needle to one side. Press the STANDBY switch and check to see that the needle returns to the center position.

60. Input Response Checks

The input response checks determine whether the autopilot performs accurately to vertical gyro and canceller inputs. To make these checks, first place the autopilot in standby condition. Then press the ENG switch and the BAR ALT switch on the control panel to engage all modes. Check the mode input responses as follows.

Note. Use a protractor (FSN 5210–541–4856) to measure the degree of gyro tilt as required in subparagraphs *a*(2) and *b*(2) below.

a. Pitch Mode Input Response Check.

(1) *Pitch canceller and C G TRIM input.*

(*a*) Set the CHANNEL SELECTOR switch to the PITCH position. Check to see that the NULL INDIC meter needle does not oscillate.

(*b*) Move the pilot's cyclic control stick smoothly fore and aft from one extreme to the other. The NULL INDIC meter needle should follow stick motion. The needle should deflect to the left when the stick is moved forward, and deflect to the right when the stick is moved aft.

(*c*) Center the stick and rotate the C G TRIM knob to center the NULL INDIC meter needle.

(*d*) Move the stock fore and aft approximately 5 $\pm\frac{3}{4}$ inches as measured at the top of the stick from the center. Be sure that the pitch servo motor hits its stops (as indicated by audible clicks) and the NULL INDIC meter needle deflects full half travel in both directions.

(*e*) Move the stick suddenly in a forward direction. Check to see that the response of the NULL INDIC meter needle is deadbeat.

(*f*) When the pitch servo motor hits its stop, as indicated in (*d*) above, rotate the C G TRIM knob $\frac{1}{4}$ turn and be sure that the motor hits the opposite end stop (as indicated by an audible click).

Note. If the servo motor is on its *right stop,* as indicated by a NULL INDIC meter needle full half travel to the right, rotate C G TRIM knob counterclockwise. Rotate C G TRIM clockwise to take the NULL INDIC meter needle off its *left stop.*

(*g*) Center the cyclic control stick, and adjust the C G TRIM knob to center the NULL INDIC meter needle.

(2) *Vertical gyro input.*

(*a*) Loosen the control gyro and amplifier on its shock mount, and raise the rear off the control gyro and amplifier (in relation to the helicopter) to produce a 5° nose-down tilt to true vertical. The NULL INDIC meter needle should move approximately one-half of half travel to the right, indicating that the vertical gyro assembly is providing proper displacement signals to the pitch mode.

(*b*) Lower the control gyro and amplifier on the shock mount. *Rapidly* raise the rear of the control gyro and amplifier (in relation to the helicopter) about 5°. The NULL INDIC meter needle should overshoot before settling in a displaced position, thus indicating proper pitch servo motor response to the rate signal generated by a sudden input.

(*c*) Secure the control gyro and amplifier in its shock mount.

(*d*) Center the NULL INDIC meter needle by moving the cyclic control stick as required.

b. Roll Mode Input Response Check.

(1) *Roll canceller input.*

(*a*) Set the ROLL RATE adjustment potentiometer on the 12-signal adjustment assembly to position 0.

(*b*) Set the CHANNEL SELECTOR switch on the motor box panel to the ROLL position. Check to see that the NULL INDIC meter needle does not oscillate.

(*c*) Move the pilot's cyclic control stick smoothly from right to left from one extreme to the other. Check to see that the NULL INDIC meter needle follows the stick motion. The needle should move to the right when the stick is moved to the right and to the left when the stick is moved to the left.

(*d*) Move the stick right and left approximately 4 $\pm\frac{1}{2}$ inches as measured at the top of the stick from the center. Check to see that the roll servo motor hits its end stops (indicated by audible clicks) and that the NULL INDIC meter needle deflects full travel.

(*e*) Move the stick suddenly, first to the right and then to the left from center. The needle should lag stick motion and settle in about 6 to 8 seconds.

(*f*) Reset the ROLL RATE adjustment potentiometer to the red dot (or position 3).

(2) *Vertical gyro input.*

(*a*) Loosen the control gyro and amplifier from its shock mount and raise the inboard end of the unit 10° $\pm$2°. The NULL INDIC meter needle should move approximately one half of half-travel to the left, thus indicating that the vertical gyro assembly is providing proper displacement signals to the roll mode.

(*b*) *Rapidly* tilt the control gyro and amplifier by lifting the inboard end of the unit about 10°. The NULL INDIC meter needle should overshoot before settling in a displaced position, thus indicating proper roll servo motor response to the rate signal generated by a sudden input.

(*c*) Secure the control gyro and amplifier in its shock mount.

(*d*) Center the NULL INDIC meter needle by moving the cyclic control stick as required.

c. Yaw Mode Input Response Check.

(1) Set the CHANNEL SELECTOR switch on the motor box panel to the YAW position. Check to see that the NULL INDIC meter needle does not oscillate when the cyclic control sticks are not actuated.

(2) Rotate the YAW TRIM control smoothly and slowly at least 1 revolution in a clockwise direction. Check to see that the NULL INDIC meter needle follows the trim control motion and moves full half-travel to the left.

(3) Rotate the YAW TRIM control 7° $\pm$2° in either direction. Check to be sure that the yaw servo motor hits its end stop (as indicated by an audible click) and that the NULL INDIC meter needle deflects full half-travel.

Note. The YAW TRIM control index marks each represent 1°.

(4) Rotate the YAW TRIM control suddenly (3 or 4 index marks) and see that the NULL INDIC meter needle overshoots and then settles to approximately half of half-travel.

d. Altitude Mode Input Response Check.

(1) Press the BAR ALT switch and set the CHANNEL SELECTOR switch on the motor box panel to the ALT position. Check to see that the NULL INDIC meter needle does not oscillate when the cyclic control sticks are not actuated.

(2) Pinch the rubber tube leading to the altitude control (fig. 47) about 1 inch from the pneumatic fitting on the altitude control mounting base and also at a point about 1 inch from the control. See that the NULL INDIC meter needle deflects to the right at least $\frac{1}{8}$ half-travel.

(3) The NULL INDIC meter needle should return to center when the rubber tube is released.

61. Intermode Reaction Checks

The intermode reaction checks determine whether there is undesirable interference between one or more servo motors. To make these checks, first place the autopilot in standby condition; then press the ENG switch and the BAR ALT switch on the control panel to engage all modes.

a. Altitude Mode.

(1) Place the CHANNEL SELECTOR switch to the ALT position.

(2) Introduce a signal into the altitude channel by having someone pinch the rubber

tube leading to the altitude control (fig. 47) about 1 inch from the pneumatic fitting on the altitude control mounting base and also at a point about 1 inch from the control. See that the NULL INDIC meter needle deflects to the right at least one-eighth of half-travel.

(3) Rotate the CHANNEL SELECTOR switch to the PITCH, ROLL, and YAW positions. Be sure that the input to the altitude channel does not affect any of the other modes and that the NULL INDIC meter needle does not move.

b. Roll Mode.

(1) Rotate the CHANNEL SELECTOR switch to the ROLL position.

(2) Introduce a signal into the roll channel by moving the cyclic control stick to the right. The NULL INDIC meter should move to the right.

(3) Rotate the CHANNEL SELECTOR switch to the PITCH, ALT, and YAW positions and check to see that the input to the roll channel does not affect any of the other modes and that the NULL INDIC meter does not move.

c. Pitch Mode.

(1) Rotate the CHANNEL SELECTOR switch to the PITCH position.

(2) Introduce a signal into the pitch channel by moving the cyclic control stick forward. The NULL INDIC meter needle should move to the left.

(3) Rotate the CHANNEL SELECTOR switch to the ROLL, ALT, and YAW positions and check to see that the input to the pitch channel does not affect any of the other modes and that the NULL INDIC meter does not move.

d. Yaw Mode.

(1) Rotate the CHANNEL SELECTOR switch to the YAW position.

(2) Introduce a signal into the yaw channel by rotating the YAW TRIM control clockwise. The NULL INDIC meter needle should move to the right.

(3) Rotate the CHANNEL SELECTOR switch to the ROLL, ALT, and YAW PITCH positions and see that the input to the yaw channel does not affect any of the other channels and that the NULL INDIC meter does not move.

62. Yaw Control System Check

Note. Use a spring scale (0 to 105 pounds) to measure the pedal forces as required in subparagraph *d* below.

a. Proportional Band Check. The proportional band check determines the distance the mechanical input linkage to the open loop spring cylinder travels before actuating the open loop spring.

(1) Press the ENG switch on the control panel.

(2) Set the CHANNEL SELECTOR switch to the YAW position.

(3) Slowly rotate the YAW TRIM knob in a clockwise direction until the tail rotor pedals begin to move. (Right pedal will move aft, left pedal will move forward.) Observe the NULL INDIC meter needle when the pedals begin to move. The meter should indicate at least one half of half-travel to the right.

(4) Slowly rotate the YAW TRIM knob in a counterclockwise direction until the pedals begin to move. (Right pedal will move forward, left pedal will move aft.) Observe the NULL INDIC meter needle when the pedals begin to move. The meter should indicate at least one half of half-travel to the left.

(5) Center the NULL INDIC meter needle with the YAW TRIM knob.

b. Open Loop Pedal Rate Check. The open loop pedal rate check determines the damper characteristics of the open loop spring by checking the rate at which the yaw open loop spring operates.

(1) Press the ENG switch on the control panel.

(2) Operate the OVERRIDE CHECK switch to the LEFT FWD DOWN position. The tail rotor pedals should move to the extreme positions, fully extended and opposite each other (right pedal aft, left pedal forward).

(3) When the pedals stop moving, place the OVERRIDE CHECK switch to the RIGHT AFT UP position and measure the time between the start and stop of pedal motion. (Right pedal moves to forward position and left pedal moves to aft position.) The time interval should be between 24 to 28 seconds.

(4) Repeat procedures given in (2) and (3) above starting with the OVERRIDE CHECK switch in the RIGHT AFT UP position.

Caution: **Restore the OVERRIDE CHECK switch to the center position after completing checks.**

c. Pedal Damper Spring Check. The pedal damper spring check determines the damper spring action by checking the response of the tail rotor pedals to a sudden input signal.

(1) Press the ENG button on the control panel.

(2) Center the cyclic control sticks.

(3) Move the OVERRIDE CHECK switch to one position and then back instantaneously. The tail rotor pedals should jump about 1 inch and then return to their original positions.

(4) Move the OVERRIDE CHECK switch to the other position and then back instantaneously. The pedal jump should be in the opposite direction.

Note. If friction force is 15 pounds at the pedal, the jump will be only ¼ inch. If friction force is 25 pounds, there will be no pedal jump.

(5) Return the OVERRIDE CHECK switch to the center position.

d. Pedal Override Force Check.

The override force check determines the force required by the pilot or copilot to override the force acting on the tail rotor pedals from the autopilot system.

(1) Press the ENG switch on the control panel.

(2) Connect one end of a spring scale to the pilot's *left* tail rotor pedal.

(3) While holding the other end of the spring scale, move the OVERRIDE CHECK switch to the LEFT FWD DOWN position. Measure the force required to stop pedal movement. The force should not exceed 40 pounds.

(4) Allow the pedals to continue their full travel and stop.

(5) Measure the force required to move the pedals in the opposite direction. The overriding force should not exceed 105 pounds and the pedals should reach full travel within 28 seconds.

(6) Operate the OVERRIDE CHECK switch to the center position.

(7) Connect one end of the spring scale to the pilot's *right* tail rotor pedal.

(8) Repeat the procedures given in (3) through (5) above with the OVERRIDE CHECK switch in the RIGHT AFT UP position.

(9) Repeat the procedures given in (2) through (8) above for the copilot's tail rotor pedals.

(10) Return the OVERRIDE CHECK switch to the center position after completing check of copilot's pedals.

CHAPTER 5

UNPACKING AND PREPARATION FOR SHIPMENT OR LIMITED STORAGE

63. Unpacking and Checking Unpacked Equipment

Note. Do not destroy or discard the containers and packing material in which the components of Autopilot AN/ASN–23 are packed; they are resuable for shipment or limited storage (par. 64) and should be stored for use as required.

a. Packaging Data. When packed for shipment, the components of Autopilot AN/ASN–23 are packed in individual metal or corrugated containers. Individual components may have been shipped separately or consolidated in any combination as required to facilitate shipment. Figure 62 shows typical packaging for those components shipped in metal containers and for those components shipped in corrugated containers.

b. Removing Contents from a Metal Container (fig. 62). To unpack a component which was shipped in a metal container, perform the steps outlined below.

(1) Remove the sealing ring from the metal container.

(2) Remove the cover.

(3) Carefully remove the formed hair latex packing material containing the component from the container.

(4) Separate the two halves of the hair latex packing material and remove the wrapped component.

(5) Open the barrier material bag and remove the component.

c. Removing Contents from a Corrugated Container (fig. 62). To unpack a component which was shipped in a corrugated container, perform the steps outlined below.

(1) Open the corrugated container and carefully lift the barrier material bag containing the component from the container.

(2) Open the barrier material bag and remove the barrier material, dessicant, humidity indicator, and the component from the bag.

d. Checking Unpacked Equipment.

(1) Checking the components against the packing list.

Note. When no packing list accompanies the equipment, the table of components (TM 11–6615–202–12, par. 5) may be used as a general check to indicate the equipment which *probably* was packed.

(2) Visually inspect the components for any signs of damage which might have incurred during shipment. If the components appear to have been damaged, refer to paragraph 2, TM 11–6615–202–12.

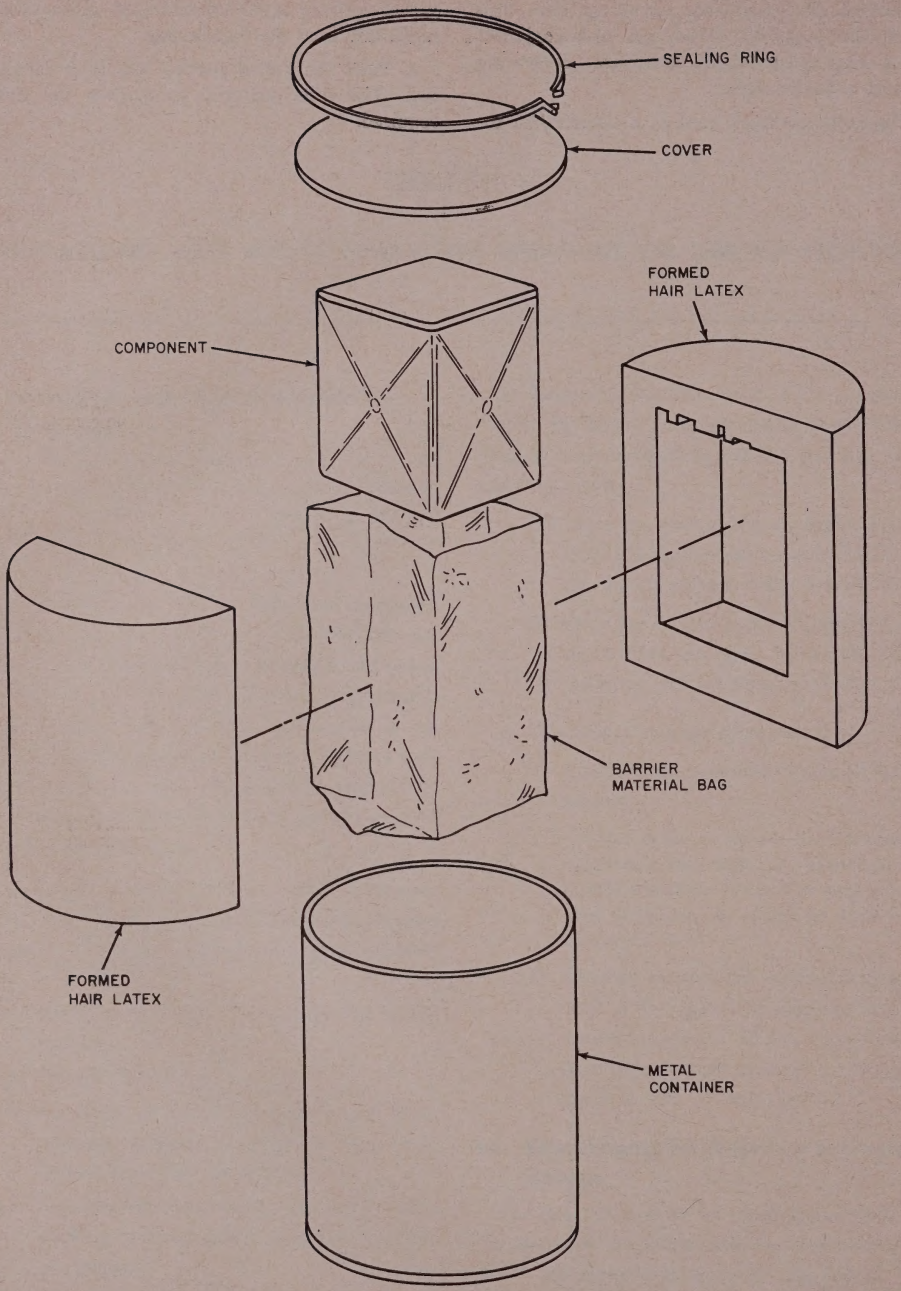
64. Repackaging for Shipment or Limited Storage

The exact procedure for repackaging depends on the material available and the conditions under which the equipment is to be shipped or stored. Adapt the procedures outlined below whenever possible.

a. Cushion the component on all surfaces with pads of filler material. Place the cushioned unit within a wrap of corrugated cardboard. Secure the wrap with adhesive tape.

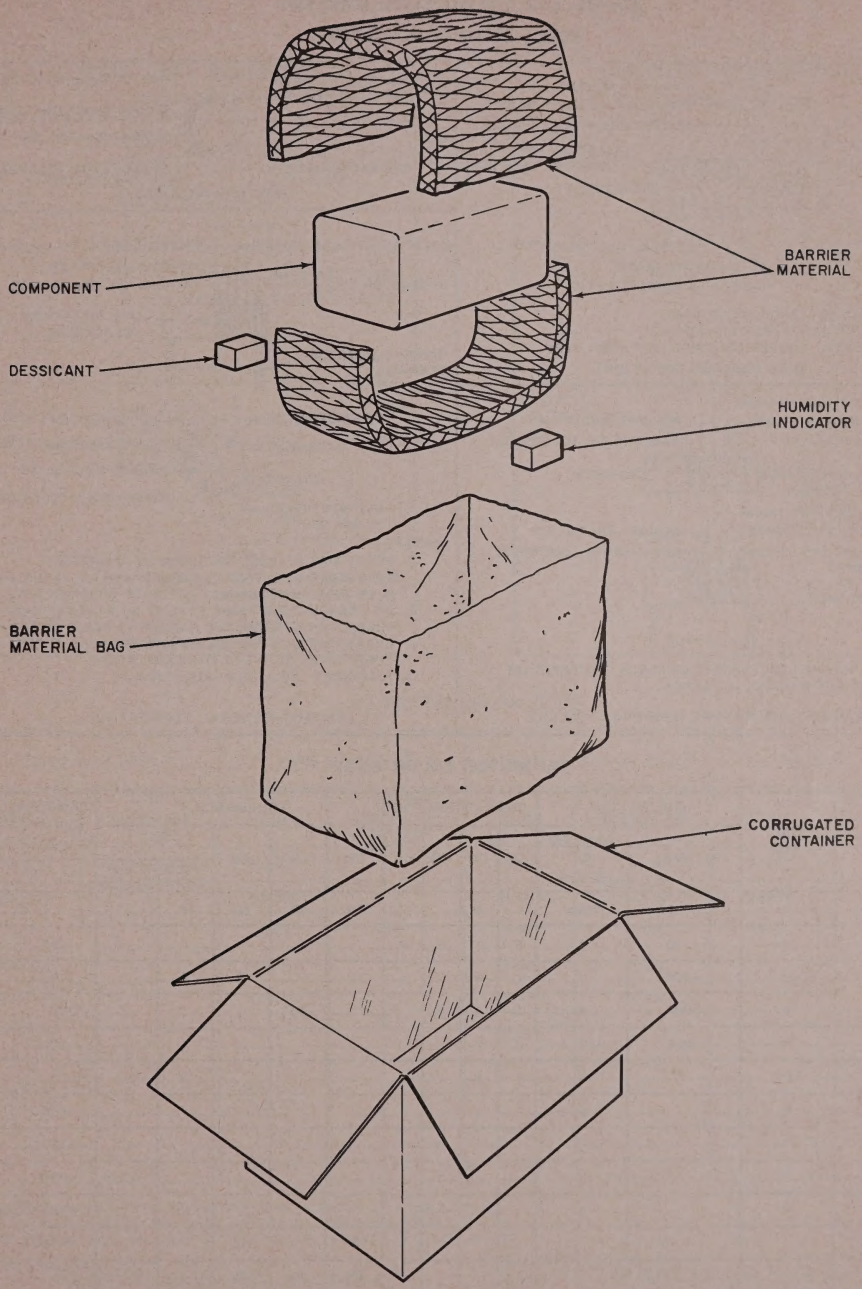
b. Place the packaged unit in a barrier bag together with an activated desiccant and a humidity indicator. Seal the barrier bag.

c. Pack the sealed barrier bag in a corrugated box. Use filler material to cushion the item as required.



1

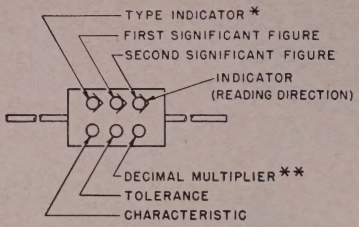
Figure 62. Typical packaging and unpacking of Autopilot AN/ASN–23 components.



2

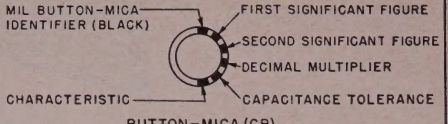
Figure 62—Continued.

CAPACITOR COLOR CODE MARKING
(MIL-STD CAPACITORS)

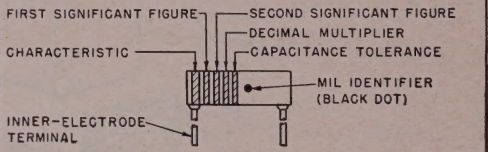


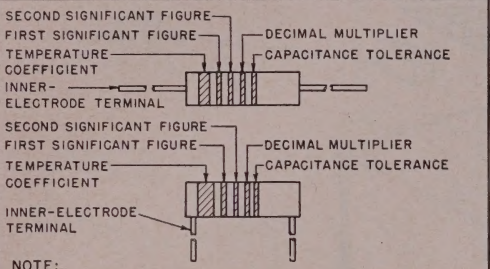
* BLACK DOT: MICA DIELECTRIC
SILVER DOT: PAPER DIELECTRIC
**INDICATES NUMBER OF ZEROS ON PAPER TYPE.

MICA (CM) AND PAPER (CN)



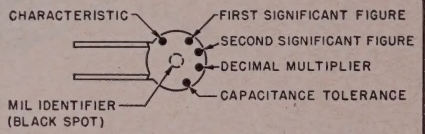
BUTTON-MICA (CB)





NOTE:
SPOTS MAY BE USED INSTEAD OF BANDS; TEMPERATURE COEFFICIENT MARKING IS LARGER.

CERAMIC-TEMPERATURE COMPENSATING (CC)



NOTES:
1. SPOTS MAY BE USED ON TUBULAR CAPACITORS; CHARACTERISTIC SPOT IS LARGER AND MIL IDENTIFIER IS ON SIDE DIAMETRICALLY OPPOSITE COLOR SPOTS.
2. MIL IDENTIFIER OF DISK TYPE IS ON REVERSE SIDE; CHARACTERISTIC SPOT IS LARGER OR SPACE BETWEEN CHARACTERISTIC AND TOLERANCE SPOTS IS THREE TIMES SPACE BETWEEN ADJACENT SPOTS.
3. TOLERANCE: YELLOW, +100%, -20%.

CERAMIC-GENERAL PURPOSE (CK)

CAPACITOR COLOR CODE

COLOR	SIG FIG.	MULTIPLIER		CHARACTERISTIC[1]				TOLERANCE[2]					TEMPERATURE COEFFICIENT (UUF/UF/°C)
		DECIMAL	NUMBER OF ZEROS	CM	CN	CB	CK	CM	CN	CB	CC		
											OVER 10UUF	10UUF OR LESS	CC
BLACK	0	1	NONE		A			20	20	20	20	2	ZERO
BROWN	1	10	1	B	E	B	W				1		-30
RED	2	100	2	C	H		X	2		2	2		-80
ORANGE	3	1,000	3	D	J	D			30				-150
YELLOW	4	10,000	4	E	P								-220
GREEN	5		5	F	R						5	0.5	-330
BLUE	6		6		S								-470
PURPLE (VIOLET)	7		7		T	W							-750
GRAY	8		8			X						0.25	+30
WHITE	9		9								10	1	-330(±500)[3]
GOLD		0.1						5		5			+100
SILVER		0.01						10	10	10			

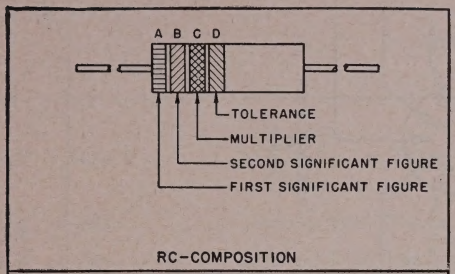
1. LETTERS ARE IN TYPE DESIGNATIONS GIVEN IN MIL-C SPECIFICATIONS.
2. IN PERCENT, EXCEPT IN UUF FOR CC-TYPE CAPACITORS OF 10 UUF OR LESS.
3. INTENDED FOR USE IN CIRCUITS NOT REQUIRING COMPENSATION.

STD-CI

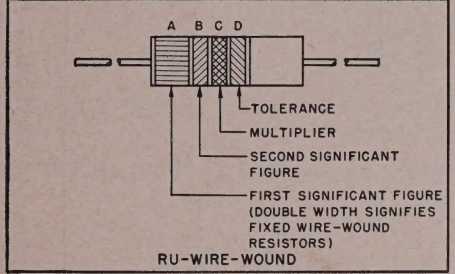
Figure 63. MIL-STD capacitor color code markings.

RESISTOR COLOR CODE MARKING
(MIL-STD RESISTORS)

AXIAL-LEAD RESISTORS (INSULATED)

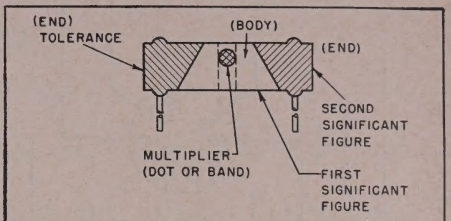


RC-COMPOSITION

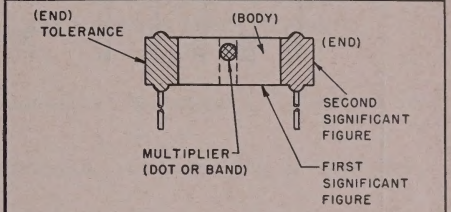


RU-WIRE-WOUND

RADIAL-LEAD RESISTORS (UNINSULATED)



RZ-COMPOSITION



RZ-COMPOSITION

RESISTOR COLOR CODE

BAND A OR BODY*		BAND B OR END*		BAND C OR DOT OR BAND*		BAND D OR END*	
COLOR	FIRST SIGNIFICANT FIGURE	COLOR	SECOND SIGNIFICANT FIGURE	COLOR	MULTIPLIER	COLOR	RESISTANCE TOLERANCE (PERCENT)
BLACK	0	BLACK	0	BLACK	1	BODY	± 20
BROWN	1	BROWN	1	BROWN	10	SILVER	± 10
RED	2	RED	2	RED	100	GOLD	± 5
ORANGE	3	ORANGE	3	ORANGE	1,000		
YELLOW	4	YELLOW	4	YELLOW	10,000		
GREEN	5	GREEN	5	GREEN	100,000		
BLUE	6	BLUE	6	BLUE	1,000,000		
PURPLE (VIOLET)	7	PURPLE (VIOLET)	7				
GRAY	8	GRAY	8	GOLD	0.1		
WHITE	9	WHITE	9	SILVER	0.01		

*FOR WIRE-WOUND-TYPE RESISTORS, BAND A SHALL BE DOUBLE-WIDTH. WHEN BODY COLOR IS THE SAME AS THE DOT (OR BAND) OR END COLOR, THE COLORS ARE DIFFERENTIATED BY SHADE, GLOSS, OR OTHER MEANS.

EXAMPLES (BAND MARKING):
10 OHMS ±20 PERCENT: BROWN BAND A; BLACK BAND B; BLACK BAND C; NO BAND D.
4.7 OHMS ±5 PERCENT: YELLOW BAND A; PURPLE BAND B; GOLD BAND C; GOLD BAND D.

EXAMPLES (BODY MARKING):
10 OHMS ±20 PERCENT: BROWN BODY; BLACK END; BLACK DOT OR BAND; BODY COLOR ON TOLERANCE END.
3,000 OHMS ±10 PERCENT: ORANGE BODY; BLACK END; RED DOT OR BAND; SILVER END.

STD-RI

Figure 64. MIL-STD resistor color code markings.

NOTES

1. DO NOT ATTEMPT TO MAKE RESISTANCE MEASUREMENTS WITH POWER ON.
2. ALL MEASUREMENTS ARE MADE FROM TEST POINT TO GROUND (CHASSIS).

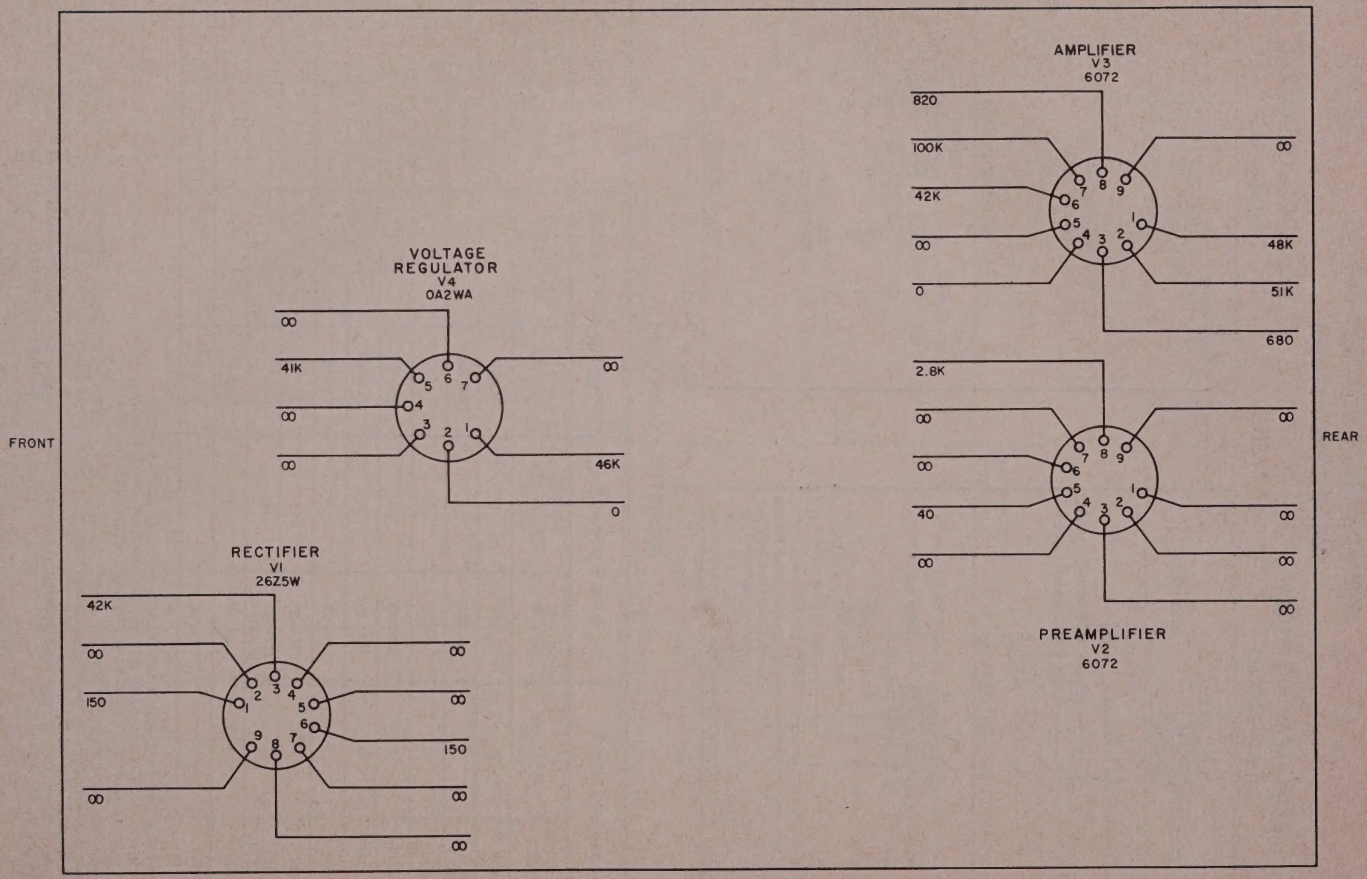


Figure 83. Gyro control and amplifier, main chassis, tube socket resistance diagram.

APPENDIX

REFERENCES

TB 11–5083–1	Test Data for Electron Test Tube Sets TV–7/U, TV–7A/U, TV–7B/U, and TV–7D/U.
TM 11–5083	Electron Tube Test Sets TV–7/U, TV–7A/U, TV–7B/U, and TV–7D/U.
TM 11–2661	Electron Tube Test Sets TV–2/U, TV–2A/U, and TV–2B/U.
TM 11–5132	Electronic Voltmeter ME–30B/U and Voltmeter, Meter ME–30A/U.
TM 11–5511	Electronic Multimeter TS–505/U.
TM 11–6625–203–12	Operation and Organizational Maintenance: Multimeter AN/URM–105, including Multimeter ME–77/U.
TM 11–6615–202–12	Operation and Organizational Maintenance, Automatic Pilot AN/ASN–23.

INDEX

	Paragraph	Page
Ac-dc interlock relay, replacement	45	110
Ac power distribution circuits	27	57
Adjustments:		
Control gyro and amplifier:		
Five-signal adjustment assembly	53*a*	120
Pitch and roll bridge	53*e*	123
Roll integrator	53*d*	122
Servo amplifier assembly gain	53*f*	123
Time delay relay K9	53*c*	122
Twelve-signal adjustment assembly	53*b*	120
Control stick canceller assembly	56	124
Motor box assembly	54	124
Time delay relay (motor release)	55	124
Altitude control assembly model No. 2203G:		
Block diagram analysis	13	20
Repair and adjustments	41	106
Schematic analysis	23	51
Altitude mode:		
Block diagram analysis:		
Input circuit	7*a*	12
Phase A, 115-volt 400-cycle line	7*c*	15
Servo amplifiers	7*b*	12
Schematic analysis	17	29
Autopilot system checks and adjustment charts	34*b*	66
Block diagram analysis:		
Altitude control assembly model No. 2203G	13	20
Altitude mode	7	12
Control gyro and amplifier assembly	9	16
Control panel assembly model No. 2560E	8	15
Control stick canceller assembly model No. 9110	12	19
Flight control switches and external relays	24	53
Motor box assembly model No. S1645–61145	10	18
Pitch mode	5	7
Roll mode	6	10
Servo motor assembly model No. S1665–61755	11	18
Yaw mode	4	6
Checks:		
Engage error	59	129
Input response	60	130
Intermode reaction	61	131
Mode engagement	58	128
Servo motor	57	127
Yaw control system	62	132
Control gyro and amplifier adjustment	53	120
Control gyro and amplifier assembly model No. 1005N:		
Block diagram analysis:		
Altitude displacement signal	9*e*	16
Pitch displacement signal	9*b*	16
Roll displacement signal	9*c*	16
Yaw displacement signal	9*d*	16
Repair and adjustment	38	102

	Paragraph	Page
Control gyro and amplifier assembly model No. 1005N—Continued		
Schematic analysis:		
Five-signal adjustment assembly	19*g*	45
Main chassis assembly	19*b*	34
Multiple channel amplifier assembly	19*e*	40
Servo amplifier assemblies	19*f*	42
12-signal adjustment assembly	19*h*	45
Vertical gyro assembly	19*c*	36
Yaw synchronizer assembly	19*d*	38
Control linkage:		
Main rotor flight	28	58
Tail rotor flight	29	59
Control panel assembly model No. 2560E:		
Ac-dc distribution and panel lights	8*h*	16
Block diagram analysis:		
BAR ALT OFF switch S106	8*d*	15
BAR ALT switch and lamp S102	8*b*	15
C. G. TRIM control B102	8*f*	16
ENG switch and lamp S101	8*a*	15
NULL INDIC meter M101	8*e*	16
STANDBY switch S105	8*c*	15
YAW TRIM synchro B101	8*g*	16
Repairs and adjustments	37	101
Schematic analysis:		
BAR ALT OFF switch S106	18*e*	32
BAR ALT switch S102	18*c*	32
C. G. TRIM control B102	18*g*	33
ENG switch S101	18*b*	32
NULL INDIC meter M101	18*f*	33
STANDBY switch S105	18*d*	32
YAW TRIM control B101	18*h*	33
Control panel, control gyro and amplifier, and motor box, replacement of parts	52	115
Control stick canceller assembly model No. 911D:		
Adjustment:		
Pitch canceller	56*b*	126
Roll canceller	56*a*	124
Block diagram analysis:		
Pitch canceller	12*b*	19
Roll canceller	12*c*	20
Repairs and adjustments	42	107
Schematic analysis:		
Pitch canceller	22*b*	51
Roll canceller	22*c*	51
Continuity measurements, dc resistance	36	78
Dc power distribution circuit	26	55
Dc resistance and continuity measurements:		
Altitude control	36*f*	84
Control gyro and amplifier	36*b*	79
Control panel	36*a*	78
Control stick cancellers	36*e*	84
Motor box	36*c*	82
Relay coil	36*g*	84
Servo motor assembly	36*d*	83
Transformer winding and inductance coil	36*h*	85
Distribution circuit:		
Ac power	27	57
Dc power	26	55
Engage error checks	59	129
Field maintenance, scope	30	63
Figure reference chart, troubleshooting	34*a*	66

	Paragraph	Page
Five-signal adjustment assembly, control gyro and amplifier, replacement	49	111
Flight control switches and external relays:		
Block diagram analysis	24	53
Schematic analysis	25	54
Helicopter flight, theory	2	2
Input response checks:		
Altitude mode	60*d*	131
Pitch mode	60*a*	130
Roll mode	60*b*	130
Yaw mode	60*c*	131
Intermode reaction checks:		
Altitude mode	61*a*	131
Pitch mode	61*c*	132
Roll mode	61*b*	132
Yaw mode	61*d*	133
Main rotor blade:		
Forces acting on	2*b*	3
Movement	2*a*	2
Main rotor flight control linkage	28	58
Maintenance inspections, periodic and special	34*b*	66
Mode engagement check	58	128
Motor box assembly model No. S1645–61145–1:		
Adjustment	54	124
Block diagram analysis	10	18
Replacement	39	103
Schematic analysis:		
Channel disengage switches	20*b*	45
CHANNEL SELECTOR switch S1	20*i*	48
F. U. NULL potentiometer	20*f*	48
Magnetic amplifier	20*c*	45
MOTOR INPUT-MOTOR POSITION switch S2	20*h*	48
OVERRIDE CHECK switch S3	20*g*	48
TACH. GEN. potentiometers	20*d*	48
Transducer transformer T101	20*e*	48
Multiple channel amplifier and servo amplifier, replacement	47	110
Periodic maintenance inspection	34b(1)	66
Pilot's and copilot's tail rotor pedal switches	43	109
Pitch mode:		
Block diagram analysis:		
Input circuits	5*a*	7
Pitch canceller	5*c*	10
Servo amplifier	5*b*	7
Schematic analysis	15	24
Repacking for shipment and limited storage	64	134
Repair of system components, scope	46	110
Replacement:		
Five-signal adjustment assembly, control gyro and amplifier	49	111
Parts for control panel, control gyro and amplifier, and motor box	52	115
Servo amplifier and multiple amplifier	47	110
12-signal adjustment assembly, control gyro and amplifier	50	111
Vertical gyro assembly, control gyro and amplifier	51	114
Yaw synchronizer assembly, control gyro and amplifier	48	111
Replacement procedures:		
Ac-dc interlock relay	45	110
Altitude control assembly model No. 2203G	41	106
Control gyro and amplifier assembly model No. 1005N	38	102
Control panel assembly model No. 2560E	37	101

	Paragraph	Page
Replacement procedures—Continued		
Control stick canceller assembly model No. 911D	42	107
Motor box assembly model No. S1645–61145–1	39	103
Pilot's and copilot's tail rotor pedal switches	43	109
Servo motor assembly model No. S1665–61755	40	104
Time delay relay and emergency release relay	44	109
Roll mode:		
Block diagram analysis:		
Input circuit	6*a*	10
Lag circuit engaged	6*c*	12
Phase A, 115-volt 400-cycle line	6*d*	12
Servo amplifier	6*b*	10
Schematic analysis	16	27
Rotor flight control linkage	28	58
Schematic analysis:		
Altitude control assembly model No. 2203G	23	51
Altitude mode	17	29
Control gyro and amplifier assembly model No. 1005N	19	34
Control panel assembly model No. 2560E	18	32
Control stick canceller assembly model No. 911D	22	51
Flight control switches and external relays	25	54
Motor box assembly model No. S1645–61145–1	20	45
Pitch mode	15	24
Roll mode	16	27
Yaw mode	14	21
Scope	1	2
Scope of field maintenance	30	63
Servo amplifier and multiple channel amplifier, replacement	47	110
Servo motor assembly model No. S1665–61755:		
Block diagram analysis:		
Servo motor and tachometer generator	11*b*	18
Transducer	11*c*	19
Replacement of system components	40	104
Schematic analysis:		
Servo motor	21*b*	49
Transducer	21*c*	49
Servo motor checks:		
Binding	57*b*	128
Dead band	57*c*	128
Phasing and damping	57*a*	127
Special maintenance inspections	34*b*(2)	66
System block diagram analysis, general	3	5
System troubleshooting charts:		
Inflight	35*b*	74
Preflight	35*a*	67
System troubleshooting, general	34	66
Tail rotor blades	2*c*	4
Tail rotor flight control linkage	29	59
Theory, helicopter flight	2	2
Time delay relay (motor release), adjustment	55	124
Time delay relay (motor release) and emergency release relay, replacement	44	109
Tools and test equipment required for troubleshooting	33	65
Troubleshooting:		
Charts:		
Inflight	35*b*	74
Preflight	35*a*	67
Data	34	66
Procedure	31	63
Techniques	32	64

	Paragraph	Page
Turn circuit, yaw mode	4*a*	6
12-signal adjustment assembly, control gyro and amplifier, replacement	50	111
Unpacking	63	134
Vertical gyro assembly, control gyro and amplifier, replacement	51	114
Yaw control system checks:		
Open loop pedal rate	62*b*	132
Pedal damper spring	62*c*	133
Pedal override force	62*d*	133
Proportional band	62*a*	132
Yaw mode:		
Block diagram analysis:		
Phase A, 115-volt 400-cycle line	4*c*	7
Turn circuits	4*a*	6
Schematic analysis:		
Circuit operation	14*b*	21
Turn circuit operation	14*c*	23
Yaw synchronizer assembly, control gyro and amplifier, replacement	48	111

By Order of *Wilber M. Brucker,* Secretary of the Army:

L. L. LEMNITZER,
General, United States Army,
Chief of Staff.

Official:

R. V. LEE,
Major General, United States Army,
The Adjutant General.

Distribution:

Active Army:

Def Atomic Spt Agcy (5)
USASA (2)
CNGB (1)
Tech Stf, DA (1) except
  CSigO (18)
Tech Stf Bd (1)
USA Arty Bd (1)
USA Armor Bd (1)
USA Inf Bd (1)
USA AD Bd (1)
USA Abn & Elct Bd (1)
USA Avn Bd (1)
USA ATB (1)
USCONARC (5)
US ARADCOM (2)
US ARADCOM Rgn (2)
OS Maj Comd (5)
OS Base Comd (5)
Log Comd (5)
MDW (1)
Armies (5) except
  First USA (7)
Corps (2)
Div (2)
USATC (2)
Ft Belvoir (5)
Svc Colleges (5)
Br Svc Sch (5) except
  USASCS (25)
GENDEP (2) except
  Atlanta GENDEP (none)
Sig Sec, GENDEP (10)
Sig Dep (17)
Army Pictorial Cen (2)
Engr Maint Cen (1)
USA Ord Msl Comd (3)
USASSA (15)
USASSAMRO (1)
USA Sig Pub Agcy (8)
USA Sig Engr Agcy (1)
USA Comm Agcy (2)
USA Sig Eqp Spt Agcy (2)
USA Sig Msl Spt Agcy (13)
WRAMC (1)
AFIP (1)
AMS (1)
Ports of Emb (OS) (2)
Trans Terminal Comd (1)
Army Terminals (1)
OS Sup Agcy (1)
Yuma Test Sta (2)
USA Elct PG (1)
Sig Lab (5)
Sig Fld Maint Shops (3)
USA Corps (Res) (1)
JBUSMC (2)
Units org under fol TOE:
  11–7 (2)
  11–16 (2)
  11–57 (2)
  11–97 (2)
  11–117 (2)
  11–155 (2)
  11–500 (AA–EE) (2)
  11–557 (2)
  11–587 (2)
  11–592 (2)
  11–597 (2)

NG: State AG (3); units—same as Active Army except allowance is one copy to each unit.

USAR: None.

For explanation of abbreviations used, see AR 320–50.

☆ U. S. GOVERNMENT PRINTING OFFICE: 1959—520518